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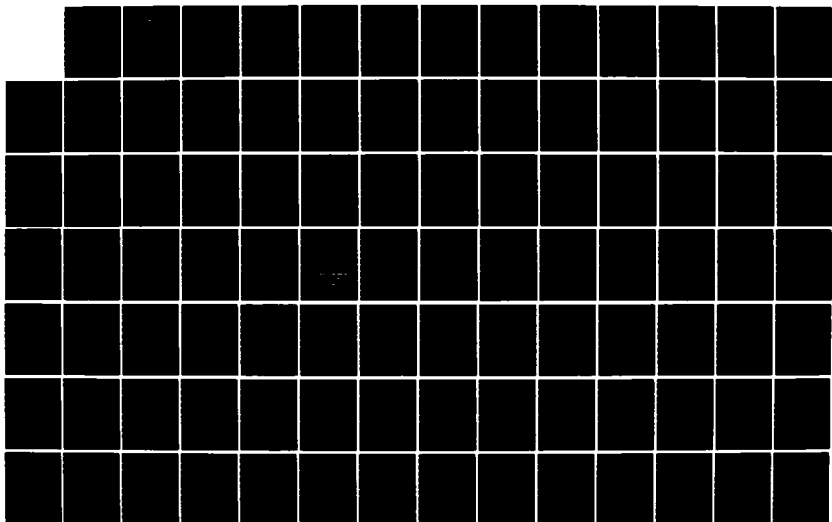
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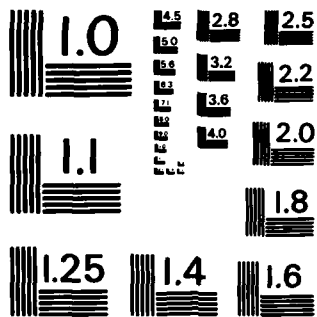
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AND AWARD METHODOLOGY
THESIS

Gary T. Sparrow James A. Stevens
First Lieutenant, USAF Captain, USAF

AFIT/GLM/LSM/84S-60

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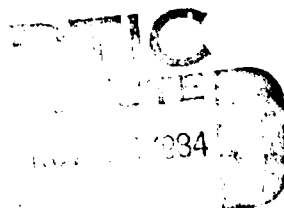
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**AN ANALYSIS OF PRODUCTION COMPETITION
AND AWARD METHODOLOGY**

THESIS

**Presented to the Faculty of the School of Systems and Logistics
of the Air Force Institute of Technology**

Air University

**In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Logistics Management**

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September 1984

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Gary T. Sparrow
James A. Stevens

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Abstract

The injection of competition into the production phase of an acquisition is an important issue in today's defense acquisition environment. Developing a second production source is the primary means of achieving this type of competition. Various techniques to accomplish production competition have been used with mixed results.

This thesis reviews the theoretical basis for and the Government's policy regarding production competition along with the determination of second source applicability to a given program. In addition, this work reviews five methods of developing a second source, along with five methodologies for determining the award between two sources. After the award methodologies are discussed, one method (the Solinsky Technique) was chosen for a more in-depth analysis.

The Solinsky award technique utilizes a continuous function which determines the quantity split as a function of the price differences proposed by the two sources. The equations used are flexible, in that they can be adjusted to reflect program management's assessment of how a given price difference translates into a split of the total quantity. However, the means of adjusting the formulas are vague and should more explicitly take into account factors, other than price, in determining the split.

This work proposes a modification to the Solinsky formulas to account for other factors, such as technical risk, in making the award determination. A decision rule heuristic was developed to serve as a guide in adjusting the modified formulas given certain objectives. An acquisition strategy was also developed around the split technique to enhance dual source competition while reducing the possibility of contractor gaming even though one contractor has limited production capability.

AN ANALYSIS OF PRODUCTION COMPETITION AND AWARD METHODOLOGY

I. Introduction and Overview

This thesis is about competition. More particularly, it is concerned with price competition during the production phase of weapons system acquisitions. This work will first present a theoretical and conceptual framework on the types of competition, followed by the concept of production competition. Next, different types of dual sourcing techniques will be discussed along with some techniques to determine how to split the contract award. Chapter III will present a split formulation that can be used to determine what quantity each contractor will be awarded. Chapter IV will validate the split formula in addition to presenting an acquisition strategy that can be used to enhance competition in a dual source acquisition.

Types of Competition

The prominent reason dual source acquisitions are desirable is the belief that competition can reduce unit costs and thus overall acquisition costs. However, this is only one facet of the subject of competition (25:4-1). Competition, as defined by the dictionary, is the "effort of two or more parties to secure the business of a third party by the offer of the most favorable terms" (26:111). Thus compe-

tition does not only involve merely cost, but also the larger category of "most favorable terms". This also includes the other competitive area of concern in the Department of Defense (DOD), design competition. Many times the term competition is used too loosely, leaving one to guess as to the type of competition referred to, when in reality design and production competition must be recognized as independent concepts (36:16).

Sellers states "design competition is the process of generating alternative potential solutions to satisfy a mission need, and the selection of the best system, price, and other factors considered" (36:17-18). The goal of design competition is to award the contract to the best technical proposal with a realistically affordable price. At the same time careful consideration is given to the impact the chosen design has on the life cycle costs (LCCs) of the system. One must also recognize that at this early stage of the acquisition cycle, LCC is merely an educated guess (36:18). It is interesting to note that there is no mention of price per unit in this phase. This is due to unit price being seen as a lower priority than design considerations. As time passes price begins to take on a larger role. Typically 80-90 percent of the total acquisition cost occurs during the production phase of an acquisition (37:10).

Thus price competition refers to the situation where the Government specifies its needs and relies on market forces to determine the price it pays for the product or service

meeting that need (44:1-1). Market forces, as used above, means there are two or more independent, qualified manufacturers for the production of identical, or functionally identical, hardware or software systems (10:56, 36:18). For price competition to exist, the Government must have a clear definition of its requirements and competent sources must be available and willing to compete. Thus design competition is used to develop a precise technical description, while price competition is dependent upon explicit specifications (45:6).

Figure 1 shows the types of competition and how they relate to the different phases of the acquisition lifecycle. The following quote provides a good summary of how the various forces of design and price competition interact throughout an acquisition:

Discussion on competition frequently leads to concentration on cost savings or price reduction. This is due in part to the belief that free-market competition is an elemental part of the free-enterprise economic system. For DOD, the benefits of competition extend beyond just cost reduction to include stimulation of innovation not only in technological and design areas, but also manufacturing; lower unit costs; satisfactory technical performance (and also quality); and a strengthened industrial base. . . . The focus on the benefits of competition shifts from one of exploiting design opportunities early in development to one of attention to the final product in terms of its unit production cost and the effect on the industrial base [28:26].

For the purposes of this thesis, competition in production will be emphasized, as it is most closely associated with price competition.

Several factors tend to minimize price competition for

weapons contracts. Systems have become highly sophisticated and increasingly complex with respect to the range of diverse technologies embodied into a single product. As mentioned earlier, a fairly definitive specification is necessary for price competition to exist. All too often the DOD has insufficiently complete, explicit, and realistic specifications. Therefore, the DOD has little confidence that contractor proposals would contain prices for the same thing (9:16).

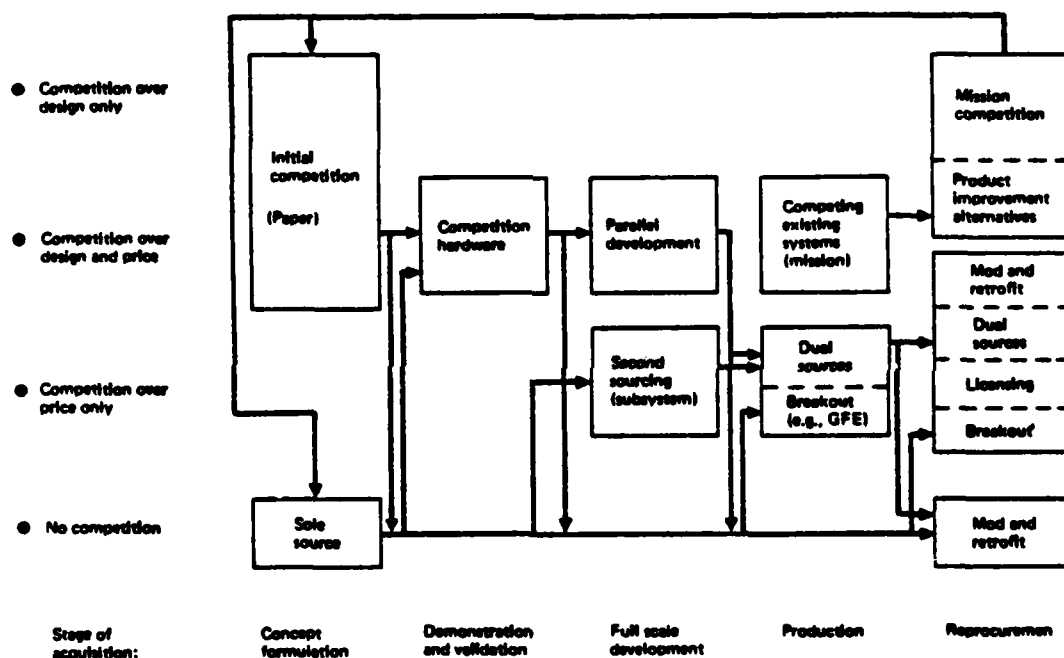


Figure 1. Types of Competition (4:7)

Conceptual Background on Competition

In this section, a theoretical framework and basis for competition are presented using micro-economic principles of perfect competition. Following this, the discussion will shift to a variation of perfect competition, effective competition.

Perfect competition exists when there are many buyers and sellers offering a standard product. No single buyer or seller maintains enough control over the market to influence price (5:3, 25:4-1, 36:20-21). There are no barriers to entry or exit from the market and both buyers and sellers have perfect knowledge of all relevant economic and technological data affecting the market (36:21).

It is obvious that a DOD program manager will not and does not desire to create a perfectly competitive market situation for several reasons. First, the Government is the only buyer, even for programs with foreign military sales (FMS) planned. Second, there are significant "barriers to entry and exit" into the DOD market place by contractors (22:48-50). Three, neither the Government (buyer) nor the contractors (sellers) have "perfect knowledge" of economic and technical data. Therefore, in most situations, the program manager will find it beneficial if he is able to create "effective" competition in the defense marketplace (36:21).

"Effective competition exists when the expected value of the benefits to be derived from competition exceed the expected costs of creating competition" (36:21). Thus the benefit and costs of having production competition must be weighed and a decision made of the net benefit (loss) to be gained from having the competition. These costs and benefits can be measured in either monetary or non-monetary terms. For example, expansion of the production base is a non-

monetary benefit. Similarly, the loss of a critical contractor due to competition could also be a non-monetary cost (36:21).

Competition, A Mixed Bag

The creation of production competition means that the Government is in a monopsonistic market position (a single buyer and two or more sellers). This swings the balance of market power over to the side of the Government. However, all is not as rosey as one might think at first glance. Usually the costs of bringing multiple sources on-line are such that generally only one other source is created in addition to the original sole source contractor. And with a smaller number of sellers the possibility of collusion is increased. Also, non-recurring start-up costs and required quantities weigh heavily on the decision to bring a second source into the production of a system (36:21). In addition, planning for production competition could add to procurement leadtime and could run counter to other DOD goals, such as multiyear procurements (17:573). Another key consideration with regards to competition is the affect of dividing the production quantity between two competitors. It also increases the cost of administering the contracts.

Learning curve theory says that as the number of units produced doubles the unit cost is reduced by some constant percentage due to "learning" (12:1). This leads to the question: Is it less costly to have one firm produce all the

items on a sole source basis in order to drive down unit cost, or should two competing firms divide the production run (19:15-32)?

Finally, if technology must be transferred between sources, there is an associated cost. This cost is usually in the form of royalties, fees, or technical assistance in various forms provided by the original source. Dual source production may increase operation and support costs because of possible differences in items produced by the two sources. This may be true regardless of the fact that each source is producing to the same set of drawings and specifications (19:15-33, 26:113).

On the other hand, competing production sources may result in lower costs, lower profits, and improved learning curves. Drinnon and Hiller (as reported in 11:38-41) hypothesized that the effect of competitive pressure was characterized by a "shift" and "rotation" in the cost improvement (learning) curve of a firm. Figure 2 displays this concept in log-linear form, where Q_1 is the cumulative number of units that had been produced prior to the introduction of competition. At Q_1 competition is introduced and the distance P_1 to A represents the immediate reduction in price due to the introduction of competition. Q_2 is the cumulative quantity produced. Assuming that the original firm won a competitive buy-out, the figure shows that the firm's price fell from P_1 , before competition, to P_2 at the end of the competition. Since the firm would have progressed along its cost

improvement curve to point B without competitive pressure, the distance BP_2 is indicative of the gross savings due to competition (11:38-39).

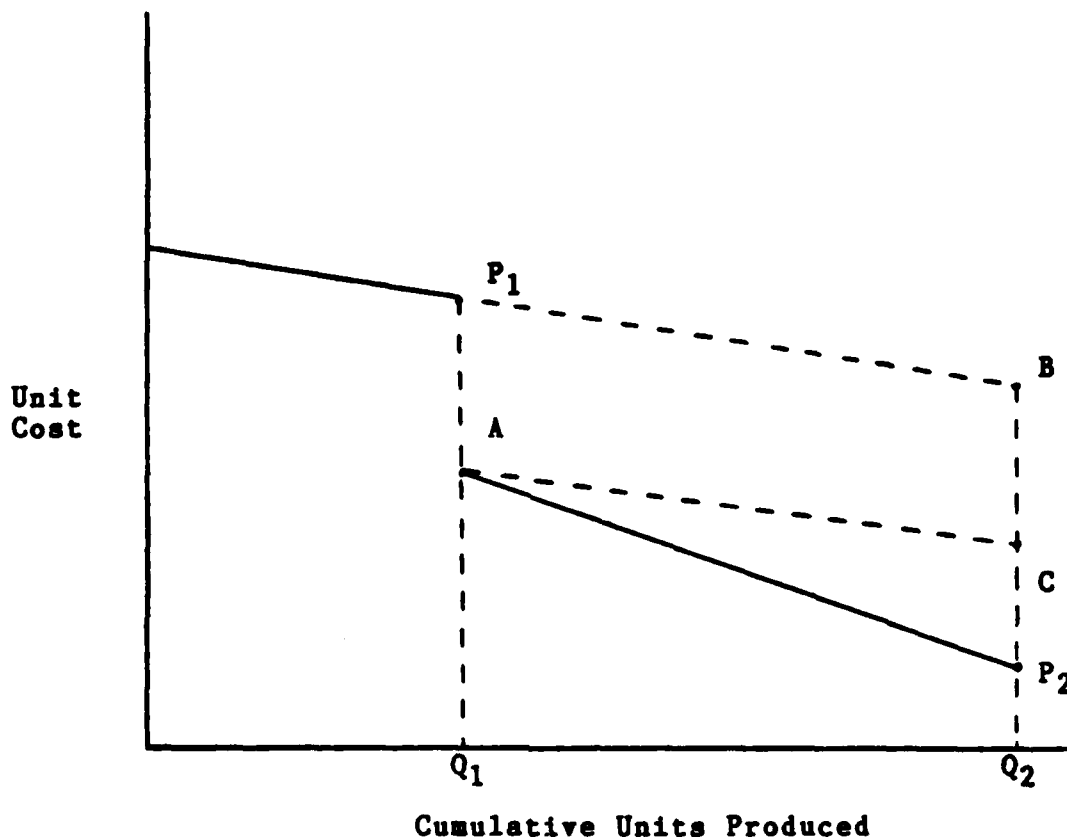


Figure 2. Effects of Competition on Cost Improvement Curve (in log-linear form)(11:39).

The parallel downward shift from B to C is characterized by the combined result of reduced profit and cost reductions which the firm developed. The reduction from C to P_2 is characterized by the firm's developing, under competition, a steeper cost improvement rate (11:39).

Firms may be more technologically progressive in devel-

oping cost-reducing design changes and improvements in manufacturing techniques and processes in order to gain advantage over their competitors (19:15-33). In interviews and meetings the authors have had with program office personnel, it has been determined that there has been a noticeable increase in the amount of value engineering change proposals (VECPs) by an original source when a second source is being developed (3). Such progressiveness by competing contractors could have long term positive impact on U.S. industrial productivity, in addition to reducing costs on the current production program (19:15-33). Other potential benefits of competition will be included when the benefits of second sourcing are discussed in Chapter II.

Current Policy and Guidance on Competition

A discussion of DOD policy and guidance on the use of competition could begin anywhere. The authors have chosen to begin with the issuance of two memorandums by the then Deputy Secretary of Defense, Frank C. Carlucci, on "Improving the Acquisition Process" (7) and "Increasing Competition in the Acquisition Process" (8). The now famous Carlucci initiatives that resulted, laid out a plan that had as an underlying theme the enhancement of competition throughout the acquisition process. In addition to the general direction from DOD for the implementation of appropriate competition enhancing programs, the Under Secretary for Research and Engineering specifically directed the services to:

1. Designate competition advocates at each procuring activity to ensure competitive opportunities are not lost.

2. Establish realistic competition goals.

3. Educate commanders on their responsibilities for maintaining maximum feasible competition.

4. Make competition in systems development and production a matter of special emphasis (emphasis added).

5. Develop procedures for identifying achievements in competing contractual requirements (15).

Secretary of Defense Weinberger followed up the initial thrust of Carlucci when, on 9 September 1982, he issued a memorandum that stated in part:

We must give greater attention to obtaining competition. . . . Competition serves to reduce cost, improve quality, and enhance the industrial base. . . . No type of purchase is automatically excluded from this direction to maximize competition [43].

The flow-down of policy on competition is evident by a policy statement issued by the Air Force Systems Command Commander, General Marsh, on 1 April 1983. It says in part that:

1. All acquisitions will be competitively awarded, unless appropriately approved.

2. Emphasis will be given to maintaining competition in production through increased use of second sourcing, component breakout and competition of alternate systems.

3. Budgets will reflect competitive plans and be reviewed by Competition Advocates.

4. Subcontract competition will be emphasized with the prime contractor.

5. Programs will be established to educate personnel on the benefits of competition and recognized competitive lessons learned.

6. Systematic constraints to competition will be resolved (17:572-573).

In addition to policy letters, various DOD instructions contain policy on competition. The instructions, however, are not as explicit as the policy letters on the subject of production competition, and tend to emphasize design competition. For example, the Office of Management and Budget (OMB) Circular A-109, in its general policy section, makes such statements as "encourage innovation and competition in creating. . . alternate system design concepts" (31:3). Department of Defense Instruction (DODI) 5000.2 requires the program manager to specifically address their plan for competition in all phases of the acquisition life-cycle (13:1). Sellers, in his thesis, states:

. . .that in the one hundred or more instructions applicable to management of major systems acquisition, there is no mention of the types of possible production competition or method by which production competition can or should be generated [36:35].

Recently, however, the Office of Federal Procurement Policy issued policy to limit sole source contracting. It states that competitive awards are required except in seven circumstances. The third exception states in part that:

. . .competitive procedures shall be used unless. . . the following circumstances require the use of non-competitive procedures:. . . (3)(ii) An award must be made to a specified source or sources to establish or maintain and alternative source which will likely increase or maintain competition and will likely result in lower overall cost to the Government [32:454-455].

Now that some background has been laid, the authors will introduce the concept of second sourcing and present a historical perspective of the concept. This will be followed by

the author's problem statement, objectives, and research questions.

Introduction to Second Sourcing

Dr. Jacques S. Gansler made the following observation in his book entitled The Defense Industry:

An important distinction often overlooked in government procurement practices is the difference between competition for an award and continuing competition during the execution of the contract. In the former case an initial award is made, often after severe competition, then there is only one source for the product from that time on. This is the case for most military acquisitions. Thus, even though a competition was held for the design of a new system, its production has almost always been done on a sole-source basis. This distinction is often not considered when proponents of the current procedure state what percentage of military systems are procured competitively, and it contrasts with the normal civilian practice of maintaining competition during a products entire acquisition cycle [22:297].

Second sourcing (or dual sourcing, as it is often called) is the name given to a group of techniques that has as a goal the maintenance of competition during the production phase of an acquisition. Competition is less common in the production phase of military systems acquisition than in the development phase. However, competition for production is generally considered beneficial for system performance, system availability, total program cost, and the health of the industrial base (20:1). These techniques are important when a noncompetitive, complex item is to be produced. Efforts to create an alternative source are largely limited to specilized high-dollar procurements. For common items, competitive pressures

in the economy create multiple sources. Equipment and systems for military application tend to be non-standard, highly complex, uniquely developed and expensive (38:214-215).

Thus second sourcing is not casually introduced in the production phase of weapon system development. "Rather, successful second sourcing is the product of considerable preparation and planning that starts in the earliest days of the program" (39:1). Usually a series of conscious decisions are made with second sourcing in mind. The decision to create a second source is an investment decision. It invariably requires the financing of technology transfer in various forms (i.e., rights to data, production expertise, and design philosophy) from the originating source to the second source. The investment is made when future benefits can only be estimated (38:215).

Certain elements of a program increase the probability of success of dual sourcing. They include: 1) High quantity with long-term production needs, 2) Capacity constraints of the current producers, 3) Potential for commercial use and 4) Design stability. The most important is the requirement for substantial long-term production. If requirements are short term, even if substantial, the benefits of second sourcing cannot be realized due to the time required for qualification of the new source (38:215-216). Chapter II will discuss the factors affecting the decision to second source. The potential costs and benefits of the second

sourcing decision will be presented along with the various techniques of second sourcing and when they are applicable.

Early History of Second Sourcing

During World War II and the Korean period, the primary reason for second sourcing was to achieve a rapid build-up of war materiel production. Thus there were five production sources for the B-24, four for the B-29, three for the B-17, and three for the Navy F4U-1 Corsair fighter. During the height of the Korean conflict there were at least two sources for the B-47 bomber, the F-84 fighter and several types of jet engines. When mobilization was not as critical an objective, second sources were maintained to insure production lines would not be interrupted by strikes or surprise enemy attacks. Also, dual sources were maintained for the production of precision items whose fabrication was difficult. In addition, dual sourcing was used to maintain quality and reliability of a system being produced (34:117-118).

In the early 1960's the Navy second sourced the Sidewinder missile program to generate incentives for cost reductions after one production run had been completed. Production quantities were allocated based upon success in reducing costs. The program was highly successful. Over the seven production years unit costs were reduced to one-seventh of the average cost of the first 300 units produced (34:118). Although some of the cost reductions are attributable to the learning curve effect, the slope of the curve was steeper

than for the average learning curve in other guided missile programs (34:119).

As weapons systems became increasingly complex throughout the remainder of the 1960's and 70's, production competition took a back seat to design competition. It was not until the early 1980's, when the Carlucci initiatives were presented and Gansler's critical book on the defense industry was published, that a renewed emphasis on production competition began.

Problem Statement

Given two qualified production contractors and a second sourcing methodology, what considerations need to be addressed in structuring the acquisition and determining the split?

Specific Research Objectives

The objectives of this effort are to enable a program manager to:

1. Decide if the program can be economically second sourced.
2. Learn what second sourcing methodologies are available.
3. Decide on an appropriate second sourcing methodology to maximize competition.
4. Present a methodology to determine the split award of a dual source acquisition.

Research Questions

The questions this effort will attempt to answer in the determination of an acquisition strategy and quantity split

are as follows:

1. How would the Minimum Quantity Requirement (MQR) be determined for each contractor in a dual source competition?
2. What award formulation methodology is recommended to determine the split award?
3. What acquisition strategy could be used to enhance competition in a dual source procurement?

II. Literature Review

The Decision to Second Source

The decision to develop a second source is one that should be made after careful planning and analysis. The program objectives and the objectives of second sourcing must be in harmony, at least to some minimally acceptable level, before further consideration of second sourcing is warranted. However, having decided that the acquisition objectives will support dual sourcing, one must look at the practicality of actually trying to do so.

Analysis of the Program Objectives. Normally, the overall acquisition objectives are established near the beginning of a program. In the case of major systems, a Program Management Directive (PMD) contains cost, schedule and technical objectives, as well as constraints and parameters. For less than major programs, documents similar to PMDs exist and fix the acquisition objectives. The desirability of a second source must compete with and may be contrary to some other overall program objectives. For example, adding a second source to shorten the delivery schedule may work against minimizing total program cost. Creating a second source to keep production costs low through competition may increase inventory costs (39:5-6).

Consequently, when the SPO is exploring the possibility of second sourcing, it must first consider where in the

acquisition cycle they are, what decisions have been made and how the decisions affect second sourcing opportunities. For example, if the program is in the latter stages of development, it may be difficult to initiate a second sourcing effort and the options may be quite limited. However, if the system is at the beginning of the development cycle, the SPO may have more latitude (39:6).

Second Sourcing Objectives. Assuming the program objectives will accommodate second sourcing, there must be something to be gained by adding another source. The two basic objectives of second sourcing are cost control/reduction and the assurance of adequate supply (37:12, 39:6). However, within these two broad areas are a number of more concrete subobjectives. They are as follows:

1. Lower acquisition costs through increased competition.
2. Broaden the production base in order to:
 - a. improve mobilization capabilities,
 - b. promote geographical dispersion of the industrial base to:
 1. counter an enemy threat to a concentrated industry,
 2. provide protection against possible fire, act of God, or other catastrophic failures by one contractor,
 3. qualification of additional sources with specialized technologies.
3. Increase production capacity, particularly in terms of production rate per unit of time.
4. Evening out fluctuations in the business base of individual firms caused by sole-source awards.
5. Disengagement of some government controls in the contractual relationship because of the presence of competition.

6. Improve performance of the system by the introduction of technical competition.

7. Facilitating the attainment of socio-economic goals by increased awards to minority and small/disadvantaged businesses.

8. Increased ability to meet international co-production commitments on NATO programs (27:34, 34:118, 37:12-13, 38:215, 39:6-7).

These objectives must be weighed in relation to DOD direction, USAF guidance, the PMD, exogenous (i.e., political or environmental) factors that surround the item to be produced, the producer and previous contractual arrangements (39:7). One study suggested the role of the contract itself be considered in more detail. It pointed out that contracts of the same type (i.e., Firm Fixed Price) have many aspects, such as escalation clauses, penalties, award fees, and payment ceilings that vary widely (4:vii-viii). Again conflicts may arise from the inherent impossibility of maximizing all program aspects. Management decisions will have to be made to determine which program aspects are most important (39:7).

After the objectives of the program and the objectives of second sourcing have been analyzed, there must be an identifiable advantage before beginning to consider the actual feasibility of trying to add another source. The advantage must be consistent with other program objectives and guidance and must complement the overall management approach for the system (39:7).

Barriers to Second Sourcing. Once program management decides dual sourcing is worth pursuing, they must face the

practical realities of doing so. Barriers to second sourcing are substantial, but may be overcome. One should look at the second sourcing effort from as many different perspectives as possible. Four perspectives are:

- 1) the overall technology transfer process,
- 2) the nature of the system,
- 3) the effect of the acquisition process, and
- 4) the contractors themselves are of particular importance.

Within each perspective are limitations and constraints that must be analyzed for their impact on the second sourcing decision.

Characteristics of Technology Transfer. One of the most often cited problems of second sourcing is that of transferring technology from one firm to another. Several potential problems need close analysis before dual sourcing is attempted. For example, how closely will the two firms need to work together to enable the necessary technology transfer to take place? The additional cost created by the necessity of maintaining a close relationship between the two firms may be significant in a decision to dual source. What and how much technical data will be required? A deficient data package may render it impossible to manufacture a given system without additional support (24:41). Some systems may be so complex that it is impossible to clearly transfer all information. The more complex an item is technically, the more intricate the fabrication process is, the tighter the

tolerances are, and the more difficult it will be to second source (39:10). The General Accounting Office reported the following:

For manufacturing some advanced hardware, there can never be enough data, it seems, to achieve effective transfer of the technology. The critical factors may be craftsmen's skills, ingenious processes, "tricks of the trade", and esoteric shop practices which cannot be reduced to formal, indeed informal paper [23:38].

Transferring technology normally requires the use of a data package which has been matured during production. The data must be validated or proven to be accurate and complete enough to permit production. These validated packages are typically hard to get and take very long to develop. Recent Congressional testimony illustrates this point. During testimony, Dale W. Church, Deputy under Secretary of Defense for Research and Engineering (Acquisition Policy) stated:

The reason I mention validated data packages is that their development typically takes four to five years. If you wait four or five years from the start of production to go into competition with a second source, you have built so many units that there are not enough left for the second source [42].

Other barriers one might encounter regarding technology transfer are reluctance of the developing contractor to license the use of certain trade secrets, proprietary data, or patents that were not developed under government contract (38:216, 45:108).

Characteristics of the System. Often, to gain an advantage over our enemies, weapon systems press the state of the

art. "To the extent an item is manufactured by advancing the state of the art, it is less susceptible to having a second source producer make it" (39:11).

Capital requirements needed to produce a system affect the ability of the Government to bring a second source into production. The second source contractor must see some way of recouping the investment in capital equipment before he will be willing to become a second source (39:11). Additionally, the cost of tooling and other factors of production will need to be carefully considered when making the dual sourcing decision (45:108).

Excessively long production leadtimes lessen the desirability of second sourcing by delaying its intended benefits (38:216, 39:12, 45:12). Thus, production lead time considerations argue for starting the contracting for a second sourcing effort as soon as possible. Other considerations such as design stability argue for delaying the commitment to a particular second source until the item and processes are thoroughly established. Consequently, the length of production lead time influences the decision about when to introduce the second source (39:12). Long leadtimes also add to cost of dual sourcing because of the mere time value of money.

The slope of the learning curve is another important characteristic of the system. This is somewhat related to the previous discussion on complexity, in that complexity is a factor in the determination of learning curve slope. If

the learning curve for the item is fairly shallow, the item is more susceptible to second sourcing. Conversely, if the learning curve is steep, the costs of dividing production lots between two sources may be prohibitive (39:12).

There is an impact to a second sourcing decision if the system has tight security requirements. High security limitations discourage second sourcing since the objective of security is to limit distribution of information (38:217). Also, the second source may not meet the standards required to be eligible to receive a higher clearance.

Characteristics of the Acquisition Process. As mentioned in Chapter I, one of the major determinants of successful dual sourcing is the size of the Government's total requirement for the item. Larger quantities are more easily divided between two producers. A second source may be required if quantities exceed the capacity of the original producer. Another aspect of quantity is the value of each unit. If unit value is low, expected aggregate competitive savings may be low, even with a large production run. Therefore, the total contract value must also be weighed along with the size of the production run (39:14).

Another important consideration is program stability and duration. Low quantities, either annual or total, offer reduced opportunities for competitive savings or schedule improvement. Fluctuating annual buys cause uncertainty and reluctance to bid on the part of potential second sources,

particularly if the production lead time of the item and the administrative lead time to establish a second firm are extensive (39:14, 45:107).

The development of a second source can have a significant effect on the logistic requirements of a system. A key question to be asked here is will the second source produce a system identical to the original developer's (39:14)? What is meant by identical? Does it mean only as far as form, fit, and function are concerned or is it more extensive, like interchangeability? The logistics system may have to stock separate sets of spare parts/tech orders/data to support the second sources product. This is a cost that must be considered in order to adequately assess the benefit of developing a second source.

The administrative leadtimes of developing a second source also warrant consideration. It takes time to hold a competition, conduct negotiations, do a pre-award survey, make an award, and qualify the firm's first article (39:16). Another administrative barrier to second sourcing is contractual complexity. For example, life cycle cost goals and warranty provisions in the originating contractor's contract may be difficult to enforce with the second source. Economic factors, like commercial versus military product demand and interest rates, may also affect a second sourcing decision (45:110).

Characteristics of Contractors. When the original

source has production capacity sufficient to meet the Government's needs, that source will resist any attempt to second source. No contractor wants business that traditionally has followed the development (production contract) of a system to be awarded in-part to another contractor. The extent to which the developer has engaged in subcontracting must be examined. A firm that has subcontracted extensively will not be as an attractive candidate for second sourcing as a firm with more of its work in-house (39:19).

Two other problems at the subcontractor level must be considered. First is the existence of a sole source subcontractor. This defeats the competitive attractiveness of second sourcing unless the acquisition technique can be applied at the subcontractor level (38:217). Second is the prime contractor's preference for "favorite" subcontractors. These subcontractors may be reluctant to deal with other primes and may give an inflated price for a component to a second source contractor.

A final barrier to second sourcing is the possibility there are no other contractors capable of producing the system. Consideration needs to be given to the second source's availability of technical people, familiarity with production of similar items, adequate capacity, adequate financing and proper management skills.

After completing the analysis of the program objectives, the second sourcing objectives, and the barriers to second sourcing, one should be able to make a judgement as to the

feasibility of developing a second source. The key question here is can program management better meet it's program objectives through the introduction of production competition? If the answer is yes, given the subjectivity and error probabilities in all the calculations, then program management needs to determine a methodology for developing a second source. In the next section, the authors will present a description of five major methods used to develop a second source for a weapon system. It should be noted here that there are other techniques than those described below, but they tend to be used for less complex systems. For example, a qualified products list (QPL) may be developed by having contractors submit samples of products to the Government and having them tested against a predetermined specification. Then the Government only solicits bids from contractors on the QPL (39:23).

Second Sourcing Methodologies

The five second sourcing methodologies summarized in this section are form-fit-function, technical data packaging, directed licensing, leader-follower, and contractor teaming¹.

Form-Fit-Function. This method involves introduction of a second source without need for a technical data package or

1. See article entitled "Second Sourcing: A Way to Enhance Production Competition" by Sellers in May-Jun 1983 Program Manager. This article gives a more detailed methodology, the advantages of each and a model to structure the selection of the appropriate method.

for interaction between production sources. The second source is provided with functional specifications regarding such parameters as overall performance, size, weight, external configuration and mounting provisions, and interface requirements. This is the classic "black box" concept, where it is not necessary to define the internal workings of the product. It is used frequently for the acquisition of expendable, non-repairable items where the ability of the system to perform as required is not dependent on what is inside the "box" (37:13).

Technical Data Package (TDP). This method involves use of a stand-alone technical data package to solicit proposals from contractors who may not have been involved in the initial development of the system or in initial production. Ordinarily, this is accomplished through the inclusion of the appropriate data rights clause in the original Research and Development or initial production contract. Even where no such clause exists, it may be possible to buy the data package subsequent to production. In the absence of such a clause, the original developer/producer may consider the design, or portions of it, to be proprietary, and hence may be reluctant to provide a complete TDP to the government. The cost of procuring the data package subsequent to initial production may thus be prohibitive. This method assumes that the data package is sufficient to allow production of the system by a second source (37:14).

Direct Licensing (DL). In its pure form, this method involves the inclusion of a clause in the early development phase of the contract allowing the government to reopen competition for follow-on production, select a winner, and appoint him as a licensee. Then, in return for royalty and/or technical assistance fees, the licensor (development contractor) will provide the licensee with manufacturing data and technical assistance to help the second source become a successful producer. This method involves not only the transfer of data from the developer to the second source, but also provides for the transfer of manufacturing "know-how." The developer is normally awarded the first production contract and is contractually bound to licensing a second source for production of an unspecified number of future systems. In fact, the provisions of the licensing agreement, including royalty fees, should normally become one of the source-selection criteria used in choosing the winning contractor. The original developer is incentivized to minimize his proposed cost for technology transfer in order to keep his overall cost competitive (37:15).

Leader-Follower. Under this acquisition technique the developer or sole-source of an item or system (the leader company) furnishes manufacturing assistance and know-how to the second source (follower company). This allows the follower to become a source of supply for the item or system. This acquisition technique is limited to situations when all

of following conditions are present:

1. The leader company has the necessary production know-how and is able to furnish required assistance to the follower(s);
2. No other source can meet the Government's requirements without the assistance of a leader company;
3. The assistance required of the leader company is limited to that which is essential to enable the follower(s) to produce the items; and
4. Its use is authorized in accordance with agency procedures (14:17-10).

Contractor Teams. This acquisition strategy envisions the award of a production contract to the team that eventually wins the design competition. During initial production, both contractors are required to demonstrate the capability to produce the complete system (37:15). Teaming allows members to complement the unique capabilities of each other to offer the Government the best combination of capabilities to achieve system performance, cost and delivery constraints. Teaming is primarily associated with research and development contracts where the combined expertise of two or more companies has been necessary to design and engineer products to meet complex military requirements (45:61).

Second Sourcing Allocation Techniques

Once the system program office has made the decision on which type of second sourcing methodology will be used, a determination on how the acquisition will be allocated needs to be made. There are numerous ways the allocation of a dual

source contract can be made. This work will only summarize five techniques for awarding dual source contracts. They are:

- 1) The Profit Related to Offers (PRO) Concept,
- 2) the GAU-8 ammunition method,
- 3) the U.S. Army Missile Command (MICOM) method,
- 4) the Pelzer technique, and
- 5) the Solinsky technique.

After each method is summarized, one will be chosen for an in-depth review, critical analysis, and further refinement.

The "PRO" Concept. The PRO Concept is used for dual source acquisitions where several annual acquisitions are contemplated. This concept has been previously used for the acquisition of Trident missile components. It strives to defeat pricing strategies by contractors that are not in the government's best interest (21). For example, during a dual source acquisition where an uneven split is to be awarded, and when the losing contractor's minimum award has already been established, one contractor may resign himself to the fact that he will only be able to get the lesser quantity. Therefore, he will try to maximize his profits on that quantity by raising his price. This is called "reverse competition" or a "bid-to-lose" strategy (21:1).

Under the PRO concept each offeror will receive a similar award quantity. To gain competition the profits of each competitor are adjusted based on bid cost. The winning

bidder is awarded the greater profit and the losing bidder's profit is improved as his bid approaches that of the winning bidder. Under this concept fixed price incentive contracts are awarded (21:5).

The winning contractor is awarded a contract at his proposed target cost with a given target profit. The losing contractor is awarded a contract at his proposed target cost, as long as it is within a certain percentage (i.e., 25%) of the winning bid, and a target fee based on a predetermined target profit setting formula. If the losing bidder's cost is more than, for example, 125 percent of the winning bid, an alternate target profit setting formula is used and target cost is negotiated. However, at least one of the bids must be within predetermined cost ceilings established by the Government (21:5-6).

The PRO Concept is effective for items with stable demand and where development is basically complete. Also, the concept can easily be set up so a contractor need not feel he has to bid artificially low to win.

GAU-8 Ammunition Method. The 30 millimeter ammunition for the A-10 aircraft has been purchased using dual sources. For this buy, each contractor was asked to submit proposals for three different quantities (35, 50, and 65%) of the total requirement. However, the bids were required to fall on a continuous logarithmic price curve. Each offeror was also required to submit an interpolation equation so the Government could establish a price for any given quantity on the

curve. After the proposals were received, adjustments were made to the prices "for competitive purposes" (2:2). Formulas were used for determining the average adjusted price delta between the offerors. The average price delta was then used to determine the award split using an "award matrix" (2:7). The matrix would designate a certain percentage of the production requirement be awarded each contractor based on the percentage difference in their average adjusted prices. For example, if the percentage difference in average adjusted prices was greater than .5 percent and less than or equal to 2.5 percent then a 55/45 split would result.

The split amounts were determined for three different alternatives required by the request for proposal. One alternative was for single year buys over three fiscal years. The other two alternatives were for variations of multi-year acquisitions. After all split determinations had been made, the alternatives were compared to determine the type of award most advantageous to the Government.

There are several weaknesses of this technique. The first is that as long as both contractor's proposals were within a certain price delta of each other a set split would be awarded. It does not take into account that both contractors could fix their price high, but within a percentage of each other so both contractors would get 50 percent of the award. The second possible weakness is both contractors know that the minimum award either will get is 35 percent. This is inferred by the quantities for which bids are required in

the RFP. There is the possibility a contractor would bid-to-lose by raising his prices. As a minimum the contractor bids will be higher. This is due to the contractor's lowered risk of not receiving an award. The bids may be higher because of the guaranteed minimum award.

U.S. Army Missile Command (MICOM) Method. The MICOM Method of split allocation has been used twice on two large multi-year missile (Shillelagh and TOW) acquisitions. This method only applies to acquisitions of like systems. Proposals were solicited from each producer on five different percentages (40, 45, 50, 55, and 60) of the total requirement. This was after a second source had been qualified and had produced an "education order". The lowest percentage represented the production rate each contractor needed to maintain in order to have the capability to produce the entire requirement. The request for proposal stated the awards would be made based on the lowest overall price obtained by combining the like bid quantities (30:10).

The prices submitted were grouped into three alternatives as shown in Figure 3. The price and quantity figures are hypothetical. Column 1 presents the total prices proposed for each quantity by contractor. Column 2 presents the lowest price combination in each alternative, and column 3 identifies the alternative having the lowest overall price to the Government. The award was, therefore, made to contractor "A" for the high quantity and contractor "B" for the low

quantity, resulting in a 60/40 split (30:11).

The MICOM Method has simplicity as an advantage. However, with simplicity comes inflexibility in that awards can only be made on the award percentages specified in the RFP. Also, each contractor is guaranteed at least 40 percent of the requirement. This is a disincentive for the contractor to provide his most competitive price because he knows that even if his bid is high he will still get 40 percent of the award. Finally, the method has price as its only basis for award once a contractor is qualified. This method disregards other important aspects of the second source contractor, such as technical competence and production risk.

	Quantity	Percent of Total Quantity	Column 1		Column 2		Column 3	
			Final Price Submissions		Lowest Price Combinations of Alternate Quantities		Low Price Alternate Awarded	
			Contractor A	Contractor B	Contractor A	Contractor B	Contractor A	Contractor B
Alternative A								
High Quantity	12,000	60	\$72.0	\$76.8	\$72.0		\$72.0	
Low Quantity	8,000	40	52.2	51.6		\$51.6		\$51.6
Total	20,000	100			\$123.6		\$123.6	
Alternative B								
High Quantity	11,000	55	69.3	70.8	69.3			
Low Quantity	9,000	45	58.5	58.2		58.2		
Total	20,000	100			\$127.5			
Alternative C								
Quantity to Contractor "A"	10,000	50	63.9	64.5	63.9	64.5		
Quantity to Contractor "B"	10,000	50	63.9	64.5	63.9	64.5		
Total	20,000	100			\$128.4		(Dollars in Millions)	

Figure 3. Comparison of Proposed Prices and Lowest Alternatives (30:11).

Pelzer Technique. Pelzer proposes a technique for the allocation of production requirements when two sources of supply are required for a large number of "similar" items over a period of years. However, his technique can not be used for making an allocation for the first year because part of the model relies on data from previous procurements (33:90).

The technique determines allocations based on competitive performance. Each contractor submits bids for various percentages of the total requirement. Using a formula, an annual competitive index is established for each contractor. This index is established using average unit price bids and any other competitive factor (i.e., performance requirements, acceptance rates, or schedule compliance) which the program office deems appropriate. There is no limit to the number of competitive factors that can be used, but each factor will need to be assigned a relative weight between 0 and 1. Once the annual competitive index has been established for the current year using at least one, but preferably two previous years data, an overall competitive index is computed for each contractor. This index is used in conjunction with a graphical technique to determine the allocation for each contractor for the current years acquisition (33:77-83).

The graphical technique includes provisions that enable adjustments to be made with regards to desired responsiveness to differences in the overall competitive indicies. However, no methodology is given on how to accomplish the desired

adjustments. Also, the allocation amounts are read from a graph which leaves room for error in interpretation. This is especially true when large numbers of systems are to be allocated and mere fractions of percentage points significantly affect the award each contractor will receive (33:70-76).

The greatest advantage of Pelzer's technique is that it can be applied when two sources are trying for an award to fill a need with items not "exactly" alike. The problems with this method have been explained above.

Solinsky Technique. In this technique, the percentage of the acquisition for award to each contractor is determined as a function of prices actually proposed. The Solinsky technique was developed to achieve effective competition while preserving an industrial base that is limited to two qualified sources. The formulas used in this technique can be adjusted to reflect management's assessment of how a given difference in prices proposed by two contractors should translate into a given quantity split (40).

Selection of the Solinsky Technique

The authors chose the Solinsky technique for an indepth review and analysis over the other summarized methods presented above because of its flexibility of application. Also, the formulas used in this technique have a more general application than the other techniques discussed. The Solinsky formulas are ideally suited for the typical second

sourcing scenario where one contractor develops a system and then a second source is brought on line to produce the same exact system. The second source initially has limited production capability but, as the acquisition takes place over several years, the new source becomes more competitive with the original source. Whereas under the PRO Concept, each company receives a pre-determined quantity award. The GAU-8 and the MICOM methods have similar applications as the Solinsky method, but are not nearly as flexible in determining the quantity split. The Pelzer technique has some merit, but is difficult to apply in the first two years (especially the first year) of the second source competition. Therefore, Solinsky's technique will be thoroughly analyzed in Chapter III to determine its strengths and weaknesses in determining the allocation of a dual source award.

III. Methodology of Split Formulas

Introduction

This chapter begins by defining the key terms that will be used in the ensuing discussions on the Solinsky and revised Solinsky formulas for determining the split allocation in a dual source acquisition. Following the definitions will be a detailed description of the original Solinsky model as used successfully in the purchase of 10,284 Night Vision Goggles for the Army (40:c-1). This section of the thesis also describes how the second source is qualified; how the relationship between the two company's prices affect the split award; and finally, how to apply the Solinsky formulas in the determination of the split award.

Next the authors offer an analysis of the Solinsky formulas with regards to the constants A, B, and C. Then a discussion of the modified version of the formulas, including the formulation of x with the use of the Price Factor in adjusting the two company's prices for various environmental factors, will be presented.

This chapter concludes with the presentation of a heuristic decision rule. This heuristic can be used as a general guideline for adjusting the revised Solinsky formulas to make allowances for various exogeneous and endogeneous variables.

Definitions

In this section the authors will present a discussion of six terms: Minimum Quantity Requirement (MQR), Economic Production Rate (EPR), Maximum Production Rate (MaxPR), Price Factor, Price Support, and Risk Factor. These will be used throughout Chapters III and IV. They are important concepts when a dual sourcing decision has as goals: 1) The reduction of overall cost of the acquisition, 2) determining the confining capability parameters (In the case of MQR and MaxPR) and, 3) the production rate(s) at which each contractor is most efficient.

Minimum Quantity Requirement. The MQR is determined by the system program office for each contractor. It is that rate which results in the maximum acceptable unit cost. There are many points of view to be considered when trying to determine each contractor's MQR. MQR will ultimately have some effect on the minimum award to either contractor. It should be understood that each of the contractors, because of differing management styles, facility layout, labor skill mix, and existing business base, will in all likelihood have different rates which they consider their minimum. However, a contractor could build at successively lower rates if the Government is willing to pay exorbitant prices. Therefore, the Government makes the final determination on what maximum price it is willing to pay for a given production rate.

Exogeneous factors also affect the MQR. For example,

opportunities to take advantage of quantity discounts when buying materials and purchased parts will be somewhat diminished at a low rate of production. Some subcontractors may not be willing to supply less than a minimum lot quantity, thereby causing the prime contractor to buy a larger quantity than would be used in a reasonable length of time. This results in increased inventory holding costs and a higher probability for inventory obsolescence.

Another prime consideration in determining the MQR is in-house utilization of various industrial resources like machinery, equipment, people, and special processes. Obviously, it is more efficient to make full utilization of expensive pieces of capital equipment thus reducing overhead per unit produced. Likewise, a production line must be working at a production rate where skilled employees are able to maintain sufficient proficiency in performing their assigned tasks. The production rate must allow for adequate utilization of any special processes and special purpose test equipment. For example, there are many pieces of test equipment that, if not used for some period of time, must be recalibrated or checked-out before use, which is costly and inefficient (16).

Unit cost is an important aspect to look at when considering what the MQR should be. It is generally assumed that unit cost and production rate are inversely related (6). As illustrated in Figure 4, at some low rate of production unit cost becomes intolerable. That is the rate which should

be considered the minimum when considering solely unit cost. The factors previously mentioned, other than production rate, also have an effect on unit cost.

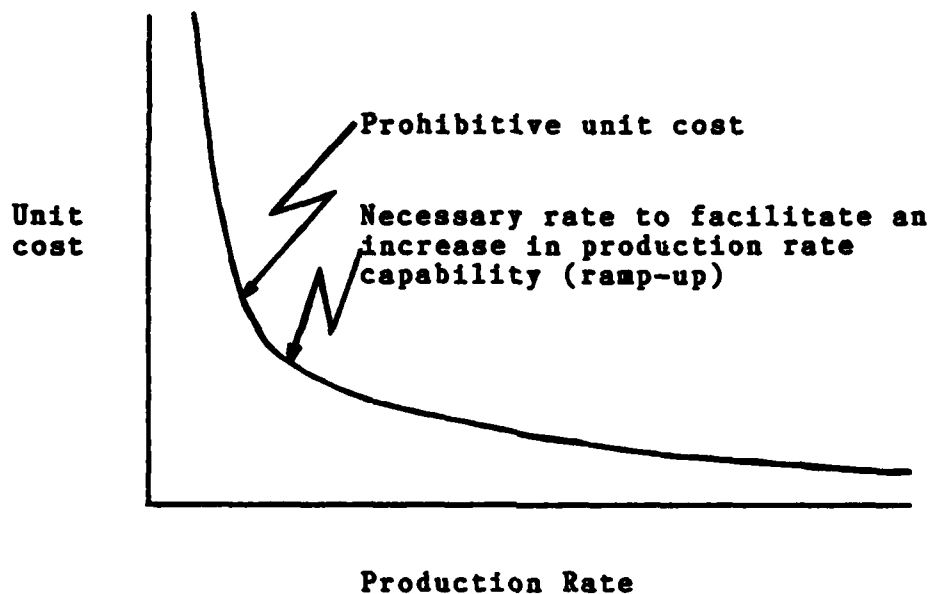


Figure 4. The General Unit Cost/Production Rate Relationship.

It is up to program management to decide at what production rate unit cost becomes prohibitive considering such things as budget constraints and units required. For example, at some level of unit cost derived from a MQR, the program office may not have sufficient funding to acquire the total number of systems needed to meet defense requirements. This would necessitate the MQR being raised to a level that resulted in lower unit costs to the government.

A method for acquiring the data needed to develop the unit cost/production rate curve depicted previously is to ask the contractor, in the request for proposal, to bid on

various quantities of the total buy. For example, on a system requiring a production rate of 300 per month, unit prices could be requested for rates of (or ranges of quantities depending on how volatile prices are at differing rates) 50, 100, 150, 200, 250, and 300 per month. Using this information, one could plot six points on a unit cost/production rate graph and fit a curve (the curve may be either curvilinear or a straight line) to those points. Consideration should be given to the extensive effort the contractors must go through in developing unit cost data on too many different production rates. However, enough points are required to develop the graph. The authors recommend that no less than five points be used with five to ten points resulting in a more definitive curve.

A final but very important aspect of the MQR that the program office needs to consider is the following: At what rate can a contractor operate and still be able to increase production capability (ramp-up) to a higher rate, without extensive delays. This is important in the event that in a future year the contractor is given a much larger portion of the split award. For example, leadtimes on tooling and test equipment may prevent a contractor going from a 20/80 split in one fiscal year to a 80/20 the next fiscal year, assuming the total requirement remains the same both years. This radical change in production requirements may cause intolerable problems for the manufacturing, buying, and possibly other functions of the firm.

The final determination of the MQR will need to be somewhere in the range between that production rate at which unit cost is too high in the mind of management and the rate which will allow for a contractor to be able to ramp-up to needed production levels for follow-on buys (see Figure 4.). Since the ramp-up constraint will usually be more confining (16), MQR will tend to be more closely associated with this rate.

The Minimum Quantity Requirement has many facets to it, namely, unit cost, learning curve effects, budgetary effects, and ramp-up/down effects. The authors have found that each dual source acquisition situation presents differing approaches in gauging what the MQR should be (F-16 Canopy, Maverick Missile, Night Vision Goggle Program and fighter engine buy).

Economic Production Rate. The Department of Defense Acquisition Improvement Program action item number seven stresses the need to reduce acquisition costs by buying systems at economical production rates. Planning to take advantage of EPRs should take place as early as the Demonstration/Validation Phase of the acquisition cycle in order to make maximum use of early contractor decisions that affect the EPR. For example, it is during this phase that decisions are made on production quantities and funding, which will largely determine if the acquisition can be acquired at an EPR (18:i).

Mr. John C. Bemis from the Office of the Under Secretary of Defense Research and Engineering (AM) has shown that, for the majority of defense acquisition programs, unit costs vary inversely with production rates (6). The logical conclusion that follows from this is that an infinite rate gives minimal cost. However, affordability considerations require that the production rate must be limited to some realistic level (18:9). "The industrial resources that determine the economic rate of procurement (production) are: tooling and test equipment, plant space, manpower and material" (18:9). Downing differentiates between economic procurement rate and economic production rate. He points out that the production rate of many manufacturers (for example, subcontractors as well as the prime contractor) has to be synthesized in developing what overall rate at which one of today's complex weapon systems should be "procured" (18). For the purposes of this work economic production rate is an equivalent term to Downing's term, economic procurement rate. Therefore, economic production rate is defined as that rate of production that permits efficient use of available industrial resources to achieve the lowest unit price to the government (1:8).

It should be noted, however, that procuring at EPRs is not always desirable and many times systems are produced at less than EPR (18:iv). For example, the Government may maintain a "warm" production base because there is no identified requirement for a follow-on system. Production rates may

also be lower than optimum due to the anticipation of a major modification to the present system's configuration (18:iv). Also, the government's total requirements may be less than a given contractor's EPR. Budget constraints would be one factor in total requirements being procured at rates other than at EPRs.

Maximum Production Rate. For purposes of this work, MaxPR is that rate at which the prime contractor will be required to add capital equipment and/or facilities or subcontract out part of the effort to increase to some higher production level.

Price Factor. The concepts of Price Factor, Price Support, and Risk Factor, relate to the equation for the formulation of x . They will be discussed in the subsection entitled Formulation of X in the section discussing the modified Solinsky formulas.

The Price Factor is a subjective adjustment made to the bid price of either the original source or the second source contractor. It is made for one of two major reasons. One reason is to adjust the bid prices (price support) to compensate the second source for a comparative disadvantage, usually because of his lack of experience. This enables him to compete until he can gain the necessary production experience. The second reason is to make an adjustment to the bid prices based on an assessment of the "Risk Factors" involved in manufacturing and assembling the system.

Price Support. An example of a Price Support might be where the price of the originating contractor, is adjusted upward by the SPO, by some amount to provide the second source some relief due to his lack of production experience. The price support is only for the purpose of making the split determination. How this is done will be discussed in the section on the Formulation of X in the modified Solinsky formulas.

Risk Factor. This is an adjustment to the low bid price prior to entering the modified Solinsky formula. An example of where a risk factor enters the model would be when the confidence level the government has in a contractor's production process is lower than the government's confidence for the same process at the other contractor's facility (35). In some instances the less experienced second source submits a bid lower than the more experienced originating source. In this instance the second source's unit price could be adjusted by the Risk Factor so that the prime contractor is awarded an equitable share of the contract.

The Solinsky Equation¹

Introduction. When considering the acquisition of weapon systems, a dichotomy exists between the goals of achieving effective competition over the procurement phase of

1. This entire section is based on an unpublished paper by Mr. Kenneth S. Solinsky entitled Procurement Strategy for Achieving Effective Competition While preserving an Industrial Mobilization Base.

the acquisition cycle, and the short-term financial considerations of obtaining the lowest priced contract for the government (40:1). The Solinsky formula discussed here is sensitive to both the long and the short range concepts. Solving the problem of maintaining an adequate industrial base can easily be accomplished by awarding two sole source negotiated contracts, on a fixed percentage of the total annual requirement, to both contractors with the lead (developing) contractor gaining the larger percentage. However, this approach, while preserving a mobilization base, introduces no effective competition into the procurement process and results in the Government paying relatively higher prices for the weapons system (40:1).

Solinsky points out that another solution to the problem of maintaining an adequate industrial base is to announce that there will be a dual source competition with fixed percentages (i.e., 60/40), of the total procurement being awarded to each contractor with the majority of the procurement quantity going to the lowest bidding responsive and responsible contractor. Quoting Solinsky, the problems with this approach are as follows:

1. A fixed quantity split results, regardless of whether the price differential is small or large.
2. One, or both, of the companies could decide that the smaller quantity is sufficient, resulting in ineffective competition or de facto competition to be the higher priced offeror (i.e., bid to lose).

3. There is no incentive for a relatively new company in the business trying to approach the price he estimates his more experienced competitor will submit. A corollary to this is that an established manufacturer, knowing that his competitor cannot beat his price, has no incentive to submit his best offer [40:1].

The following sections discuss the development and successful utilization of a procurement approach that provides for effective competition between two qualified contractors with unequal knowledge and experience in the production of a given system. The approach utilizes a mathematical formulation that determines the split award as a function of the difference in prices proposed by the two contractors (40:1). The rest of this section will describe Solinsky's equation as developed. Then following this section, the next section presents some criticisms of the Solinsky's equation and describes a variation of his formula. Following that section, some comprehensive examples will be presented in Chapter IV which will highlight many of the issues and concerns that must be dealt with in developing and acquiring weapons systems via second sourcing.

Functional Relationship Between Price Difference and Quantity Split. It was determined that prior to solicitation that the quantity split was to be awarded as a function of the differences in prices. A mathematical equation was devised to relate the difference in prices proposed by the two contractors to a split of the procurement quantity between the two companies. The equation represented management's assessment of an equitable balance between the short

range goal of procuring the current quantity at the lowest possible price, and the longer range goals of maintaining two contractors for competitive reasons and maintaining an adequate industrial base (40:2).

In the case under consideration, management determined that in order to be a viable producer, and thus an active part of the industrial mobilization base, a company needed to receive at least 10 percent of the award. Only an extremely high price differential would be seen as jeopardizing the industrial goal being sought. In the Solinsky case a 90/10 split occurs when one company's price was 50 percent higher than the other company's price (40:A-2).

Another consideration in determining the maximum and minimum awards to be given competing contractors is their ability to increase and decrease production rates when the split award ratio changes. For example, on many complex systems where long leadtimes are involved and the ability of the contractor to hire certain types of skilled labor is limited, the government may not be able to award one contractor 20 percent of the award one year and turn around and award that same contractor 80 percent the next year and expect him to perform adequately (16).

Quantity Split Formulas. The equation used by Solinsky to determine the quantity split is:

$$f_1(x) = \left[\frac{Ax}{|x|} \left(\frac{\arctan(B|x|^C)}{90} \right) + 1 \right] .5 \quad (40:B-1) \quad (1)$$

where

$f_1(x)$ = percentage of acquisition quantity to be awarded to company 1,

x = the magnitude of contractor's bid price deltas,

A, B, & C = constants \geq zero (See the section Effects of Adjustments to the Constants A, B, and C for further discussion),

and

$$x = \frac{\text{Company 2 price} - \text{Company 1 price}}{\text{Company 2 price} + \text{Company 1 price}} \quad (2)$$

(40:A-1).

Discussion of Quantity Split Formulas

Formulation of x . The value x is determined by taking the difference between the two proposed prices divided by the sum of the two prices. The formulation can result in either a positive or negative value. This is because Company 2's price can be either the higher or the lower of the two company's bids. If company 2 is the lower of the two prices x would be negative and the split value will be a number less than 50 percent for company 1. Conversely, if company 2 submits the higher of the two bids, x would be positive and the split value will be a number greater than 50 percent for company 1. Solinsky's formulation of x considers the magnitude of the price difference rather than evaluating the split based on the numerator of the equation of x . The numerator does not consider the relative significance of the difference in price only the absolute difference. For example, the

difference between two prices for an item of \$1000 and \$2000 is much more significant than the difference on another item of \$10,000 and \$11,000 even though in both cases the price delta was \$1000 (40:A-1, A-2). The value for x , however, will be identical for items with the same percentage price difference. For example, on one item contractor 1's price is \$100 and contractor 2's price is \$110. Working through the equation for x results in the value .047619. Likewise, the value for x of another item will also be .047619 if contractor 1's price is \$100,000 and contractor 2's price is \$110,000. Also, "by dividing by the sum of the prices the equation is independent of who is called company 1 and who is called company 2" (40:A-2). Solinsky feels this somewhat simplifies the Request for Proposal (41).

Now that x has been determined, the equation for determining the split can be used following the adjustments of the constants A, B, and C to reflect the program office's assessment of the competitiveness of the two contractors. This is a highly subjective area. However, it is where crucial decisions must be made since the constants A, B, and C affect the sensitivity of the $f_1(x)$ equation. This sensitivity is relative to unit price deltas which will ultimately determine the quantity split.

Effects of Adjustments to the Constants A, B, and C.
In discussing the effects of adjusting the constants in the formula, the authors will use as a baseline set of values the following: A = 1, B = 75, and C = 2. Using this set of

values for the constants results in a baseline curve that is "normal" looking. This is not "normal" in a statistical sense, but relative to curves resulting from deviations from the baseline values of A, B, and C. According to Solinsky, these baseline values were used because they made the graph scale well, however, there was no theoretical basis for these values (41). Figure 5 depicts the baseline curve as derived by Solinsky. Table I depicts price deltas with the associated values for x.

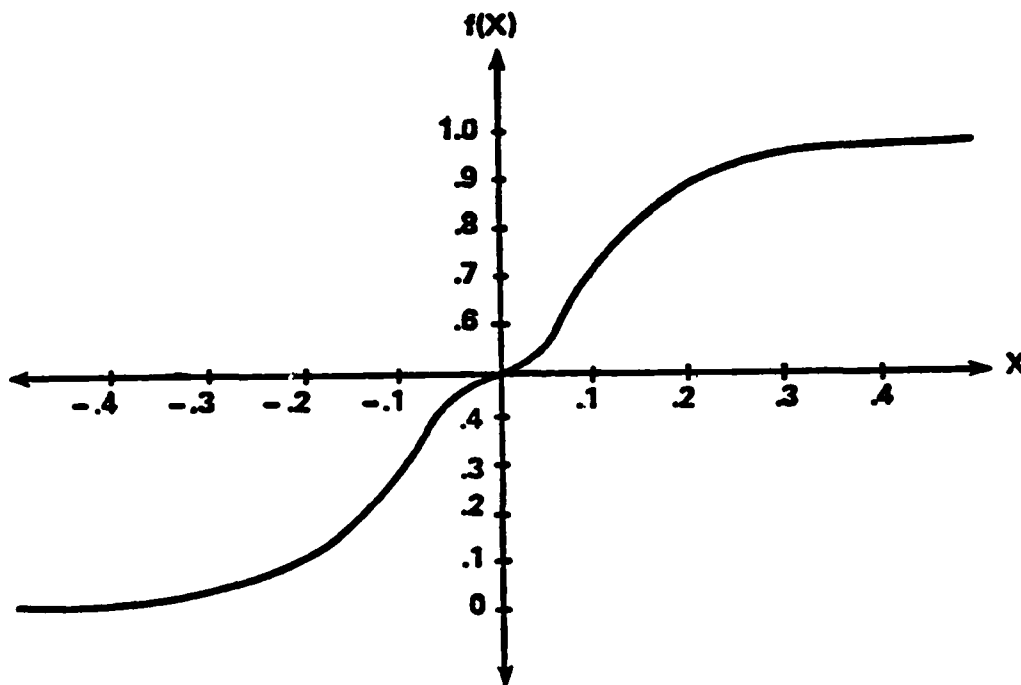


Figure 5. Solinsky's Baseline Split Curve (40:A-1).

By changing the constants, A, B, and C, the general equation can be modified to reflect a wide range of manage-

ment concepts. This is shown in figures 6, 7, and 8 which maintains two of the constants at the baseline values while varying the third. All three of the constants affect the sensitivity of $f_1(x)$ to changing values of x .

Note that constant A's primary function is to limit the "height" of the overall curve, but it also affects the slope of the curve. For example, with A set at 1.0 the maximum award possible for contractor 1 approaches 100 percent asymptotically, but with an A of .8 the maximum that can be awarded to contractor 1 will approach , but never quite get to 90 percent. Table II depicts the maximum award to contractor 1 with a given value for the constant A.

Table I
Price Deltas for Determining x

Price deltas in percent	Values for x
25%	.1111
50%	.2000
100%	.3333
150%	.4285

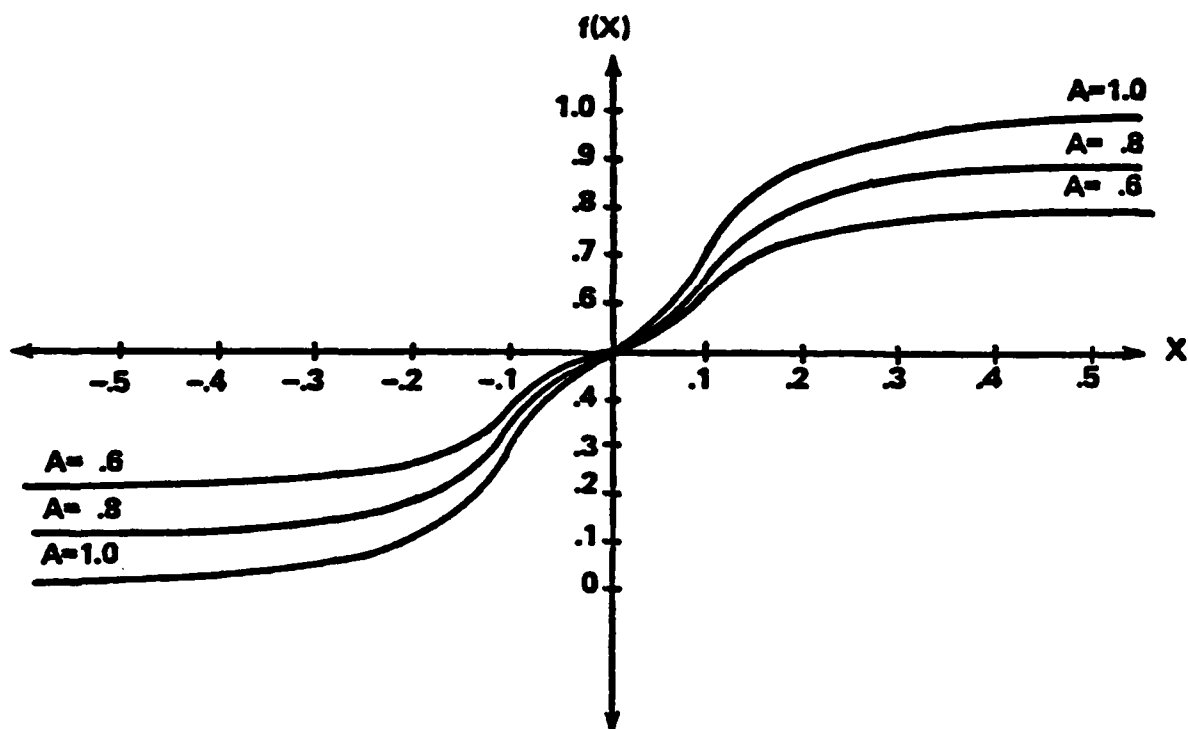


Figure 6. Affect of Changing A While Keeping B=75 and C=2 (40:B-1).

Table II

Effects of Varying the Constant A

Values for the Constant A	Maximum award to Contractor 1
1.0	100%
.8	90%
.6	80%
.4	70%
.2	60%
0	50%

Note that in Figure 7 the constant B affects the slope of the curve with larger values of B yielding a "steeper" and therefore a more price sensitive curve. This is the case when price deltas cause x to be less than .2. When x is larger than .2 the slope of the curve flattens out which indicates less sensitivity to price deltas. The value for x is greater than .2 when the price difference is greater than 50 percent.

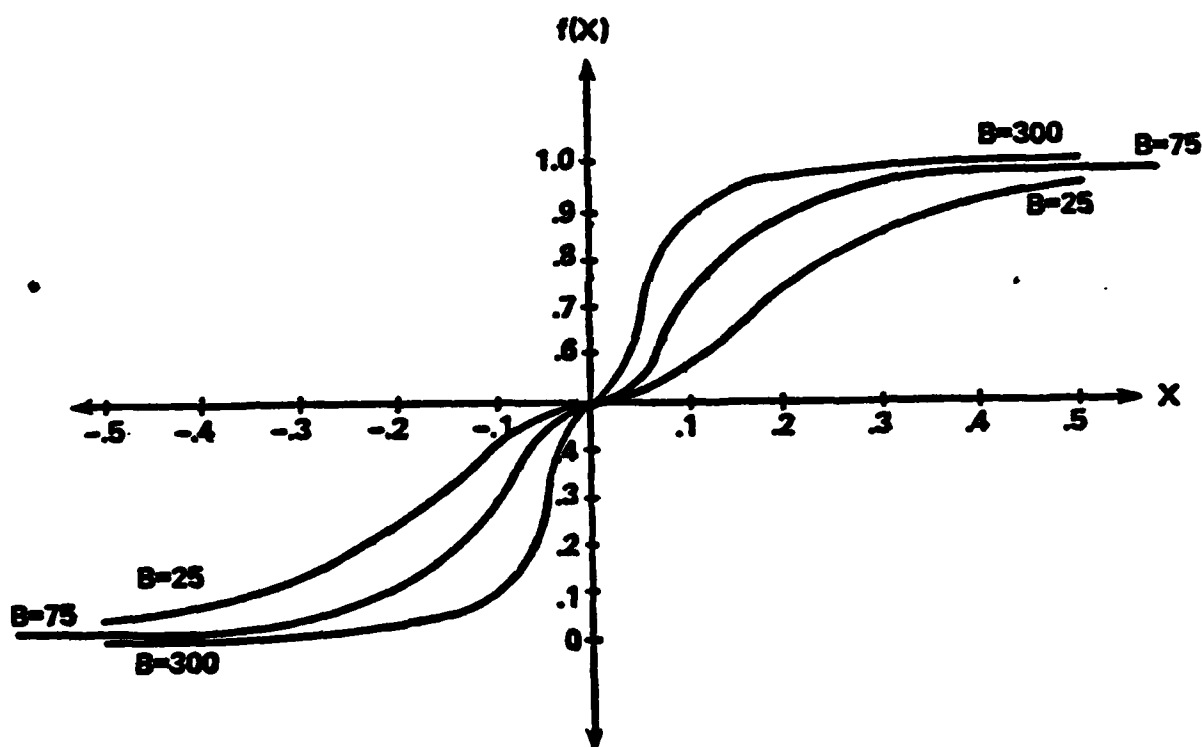


Figure 7. Affect of Changing B While Keeping $A=1$ and $C=2$ (40: $B-2$).

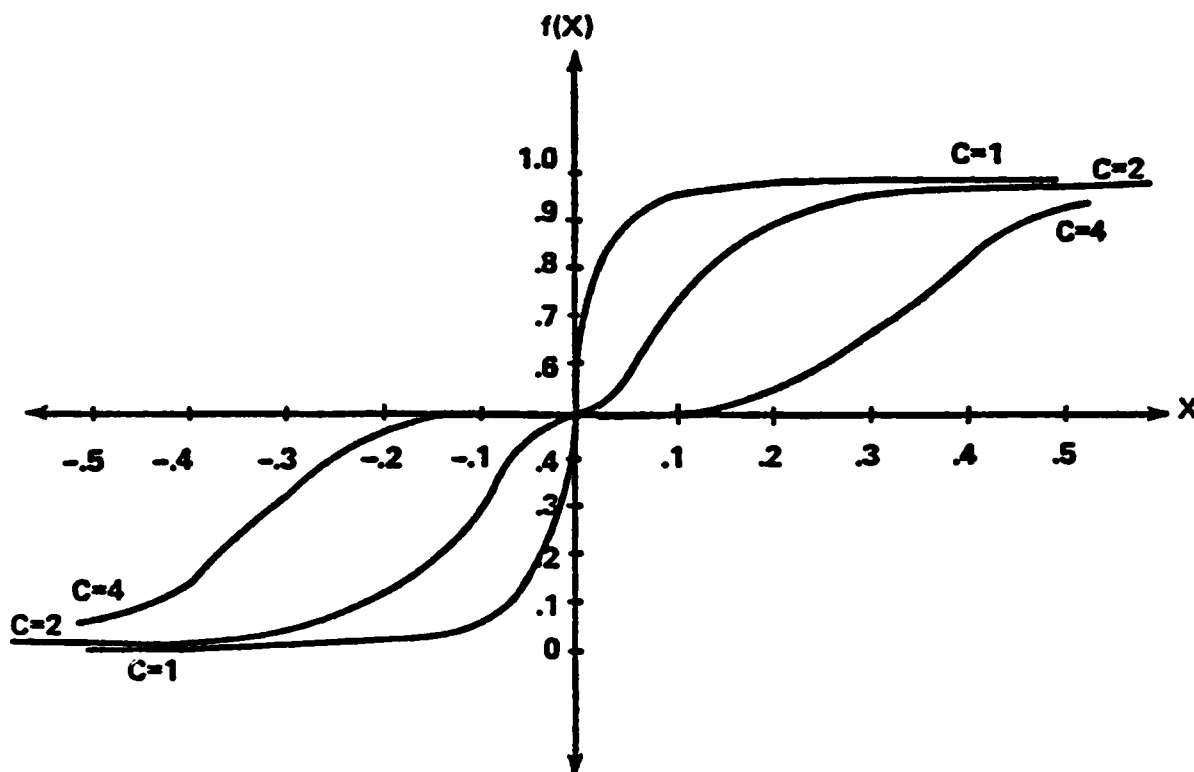


Figure 8. Affect of Changing C While Keeping $A=1$ and $B=75$ ($40:B-2$).

The effect of the constant C on the curve is somewhat similar to that of the constant B . However, C has a much more radical effect on sensitivity since it is an exponent in the formula for $f_1(x)$.

Solinsky's Split Determination Formula Discussed. As mentioned previously, the output of the $f_1(x)$ formula, after adjusting the constants A , B , and C to reflect management's view on how sensitive the equation should be relative to price deltas, gives the percentage of the acquisition quantity to be awarded to company 1. To arrive at the percentage award for company 2, one must obviously subtract from one the

percentage for company 1.

In discussing the various aspects of the $f_1(x)$ formula,

$$\text{where } f_1(x) = \left[\frac{Ax}{|x|} \left(\frac{\arctan(B|x|^C)}{90} \right) + 1 \right] .5, \quad (1)$$

the authors have elected to break the formula into parts and discuss each part separately. First, the absolute value of x raised to the C power will be discussed followed by the multiplication of $|x|^C$ by the constant B . Then the taking of the arc tan of the $B|x|^C$ quantity and dividing it by 90 will be discussed. Next the $\frac{Ax}{|x|}$ portion of the equation will be evaluated and the discussion will conclude by talking about the effects of the addition of one and the multiplication by .5 (50%) have on the outcome of the formula.

The absolute value of x , ($|x|$), is used in the $B|x|^C$ portion of the formula to ensure the resulting product is always positive. Without using $|x|$, when x is negative and the exponent C is an odd number, a negative product results which will render the output of the equation invalid. Multiplying the quantity $|x|^C$ by a positive constant (B) allows for the formula to be adjusted for sensitivity with regards to price deltas.

Taking the arc tan of $(B|x|^C)$ results in a value that approaches 90 asymptotically. When this value is divided by 90 the result will always be a positive number less than one and greater than or equal to zero. By multiplying this number by $\frac{Ax}{|x|}$ the determination is made as to the sign of

the quantity $\frac{\text{arc tan } (B|x|^C)}{90}$, which when negative and added to one, and finally multiplied by .5 will result in a split value of less than 50 percent for company 1. When the quantity $\frac{\text{arc tan } (B|x|^C)}{90}$ is multiplied by an $\frac{Ax}{|x|}$ that is positive then the resultant product will be positive. This quantity when added to one and multiplied by .5 will result in a positive fraction greater than .5. The positive constant A in the formula allows the SPO to adjust the equation based on limiting the maximum award to be given.

Drawbacks of Solinsky's Equations

Introduction. In evaluating Solinsky's formula it was found to be very effective in determining a split value. However, the formula has drawbacks that could lead to confusion on the part of program management. In the following sections these drawbacks will be discussed, then a proposed modification to the Solinsky equation will be postulated to eliminate the confusion. This should make the equation even more useful to program management and contracting officers.

Drawbacks of Varying the Constants A, B, and C. Solinsky's formula assumes that the three constants can be adjusted to any value to take into account program management's objectives (40:2). For example, if the SPO wanted to provide a price support (subsidy) to the less experienced second source, the constants could be adjusted to make the formula less sensitive to unit price deltas i.e., A=.8, B=25, or C=4. This would have the effect of making the split value

move toward the 50/50 range.

The problem with this is that Solinsky is very vague about how much the constants have to be changed to provide for a specific price support value i.e., 10%. According to Solinsky the constants would have to be changed by trial and error to get the desired results (41). However, a question that could be asked is how does one know that the selected constant values take into account the exact price support amount, no more or less. Also, when these constant values are selected, for price support, the formula loses its flexibility to adjust to any other management objective like sensitivity to price deltas or risk.

A second drawback of the Solinsky formula is with the adjustments to the constant A. As discussed previously in the section the Effects of Adjustments to the Constants A, B, and C, the primary purpose of the constant A is to limit the maximum split value. For example, if A equals .8 or .6 the maximum split award will be 90/10 or 80/20 respectively. The value for A can be assigned by program management to take into account a required minimum quantity requirement each contractor should receive to keep them as a viable producer.

The problem with adjusting A to account for a MQR is that A also has the effect of causing the formula to be less sensitive to price deltas as A gets smaller. This could be unfair to the low priced bidder. For example, if the SPO determined a MQR for each contractor was 30 percent the value

for A could be set at .4. This has the effect of limiting the maximum split to 70/30. However, the formula would produce a 70/30 split only if the values for B and/or C were such that they made the formula very sensitive to price deltas (i.e., 300 and/or 1 respectively). In most instances the formula would produce a split value less than 70/30. The MQR does not come into effect in this case. Therefore, when A is less than one, the high priced bidder has an unfair advantage. For example, when B=75 and C=2, if A=.4, a 10 percent unit price delta between competitors cause a 52/48 split. However, if A were left at 1 so as not to take into account the MQR then the split would be 55/45.

The adjustment of A could result in a significant difference in award quantities. In the example above the adjustment of A caused a 3 percent difference in the split. This could represent a significant loss to the low bidder if the procurement was for a large quantity and/or unit costs were high.

Mathematically, constant A also has the ability to cause the formula to produce an answer larger than 100 percent. This is the case when A is assigned some values greater than one. Therefore, if the constant A is used it should be limited to values that keep the split less than 100 percent.

A third drawback of the Solinsky formula is in the formulation of x , where $x = \frac{\text{Company 2 price} - \text{Company 1 price}}{\text{Company 2 price} + \text{Company 1 price}}$. When this formula is used in the $f_1(x)$ formula the company submitting the lowest unit price will always get the majority

of the acquisition. However, there may be factors, such as risk, that would dictate the company submitting the lowest bid not be awarded the majority of the acquisition. This adjustment could not be made using the Solinsky formula. Another basic weak point of the equation is when and by how much the constants A, B, and C should be changed to accurately reflect managements objectives. These objectives should encompass an equitable balance between the short-range goal of procuring the product at the lowest possible price and the long-range goal of maintaining a competitive industrial base. Solinsky does not give any basic guidelines about what values could be used to meet particular management objectives (40:2). Solinsky only mentions that;

In determining a quantity split as a function of a price difference, care must be taken to assure that the equation used accurately reflects management's acquisition concepts.... By changing the constants, A,B,C, the general equation can be modified to meet a wide range of management concepts. This is shown in figures B-1, B-2, and B-3 (Figures 6, 7, and 8 of this report) [40:B-1].

Even though any values can be used for the constants, general guidelines on types of possible management criteria and the corresponding values for the constants would be useful.

Modified Equation: Formulation of x

Price Factor. The first drawback mentioned in Solinsky's formula was the requirement to adjust the constants A, B, and C by trial and error to account for any price support factors. This limited the usefulness of the constants and, therefore, restricted the flexibility of the formula to

determine the split.

This problem can be easily eliminated by inserting a price factor variable into the formulation of x. As a result, the value of x is determined where:

$$x = \frac{\text{Company 2 price} - \text{Company 1 price} + \left(\frac{\text{Price Factor}}{100}\right)}{\text{Company 2 price} + \text{Company 1 price}} \quad (3)$$

In this formulation of x it will be assumed that the contractor submitting the lowest bid is always Company 1.

Inserting the variable, $1 + \left(\frac{\text{Price Factor}}{100}\right)$, into the numerator and multiplying by company's 1 unit price eliminates the need to adjust the constants to take into account any price support factor. Also, the variable can take into account any other factor the SPO may decide should influence the evaluation of a company's unit price. As a result, the constants in the $f_1(x)$ formula, A, B, and C, can be used exclusively to determine the split value based on x. The following is an example of determining x. This example is based on management's objective to encourage the second source to compete against the prime source by giving the second source a price support. This would tend to give the second source a relatively larger portion of the award.

The SPO may decide a price support factor of 10 percent is the maximum the second source should receive to help them be more competitive. However, if the second source's bid unit price is less than 10 percent higher than the prime source's unit price, then the price support factor should be reduced accordingly so that the low bidder receives the

majority award.

Example 1:

Price support factor = 10

Prime source's unit price = \$1000

Second source's unit price = \$1100

$$x = \frac{\text{Co. 2 price} - \text{Co. 1 price} + \left(\frac{\text{Price Factor}}{100} \right)}{\text{Co. 2 price} + \text{Co. 1 price}} \quad (3)$$

In this example, the prime source will be Company 1, because it submitted the lowest unit price bid, and the second source will be Company 2. Therefore,

$$x = \frac{1100 - 1000(1.10)}{1100 + 1000} = 0.$$

As a result of $x = 0$, each company's unit prices are considered equal and the split would be 50/50.

Example 2:

Price support factor = 10

Prime source's unit price = \$1000

Second source's unit price = \$1250

$$x = \frac{1250 - 1000(1.10)}{1250 + 1000} = .0667.$$

As a result of $x = .0667$, with the constants $A=1$, $B=75$, and $C=2$, the split determination would be as follows:

$$f_1(x) = \left[\frac{Ax}{|x|} \left(\frac{\arctan(B|x|^C)}{90} \right) + 1 \right] .5 \quad (1)$$

$$= \left[\frac{1(.0667)}{|.0667|} \left(\frac{\arctan (75|.0667|^2)}{90} \right) + 1 \right] .5$$

$$= .6025$$

Therefore, the prime's split = 60.25% and the second source's split = 39.75%.

With the inclusion of a price factor, the mathematical curve of the equation remains unchanged for any particular values for the constants. The only effect the price factor has on the outcome of the split formula is that it causes the unit price deltas to be smaller in most cases. Therefore, the split values move toward the origin of the curve or toward the 50/50 range. Now the SPO has much more flexibility in adjusting the constants to reflect it's philosophy toward the dual source acquisition. This is due to the constants not having to be adjusted and thereafter remain fixed to take into account any price factors.

Risk Factor. In most acquisitions the lowest bidder would be the one awarded the contract. In a dual source acquisition, the lowest bidder would usually be awarded the highest quantity split. However, there are instances where factors, other than unit price, such as risk, would have a significant influence in determining the award. If this is the case, the price factor variable in the formulation of x can be utilized to take into account the risk factor.

In the Solinsky formula, the lowest bidder will always get the largest portion of the split. However, there are

cases where the government may not want to award the lowest bidder the largest portion of the split. For example, a risk factor may be more critical than unit price in determining the award. There is always the possibility that the second source may submit a bid that is lower than the more experienced prime contractor's bid. However, the SPO may decide that the probability of the second source delivering on the contract is too risky to allow that contractor to get the majority of the acquisition. If this is the case, the Solinsky formula could not be used to determine the split because of its property that the low bidder will always receive the majority split.

Using the modified formulation of $f_1(x)$, the risk factor would not present a problem. In determining x in the modified $f_1(x)$ formula, the price factor now becomes the risk factor and company 1 is the high risk company submitting the lowest bid. An example of this is where company 2 is the experienced contractor and company 1 is the second source. Company 2 submits a unit price of \$110 and company 1 submits a unit price of \$100. Company 1 would get the majority of the split under conditions where both contractors produce at equal risk. However, the SPO determines that company 1 has a relatively high probability of inadequate performance if given the largest portion of the split. Therefore, a risk factor is determined by the SPO to be applied to contractor 1's unit price. This risk factor would have the effect of

taking away company 1's unit price advantage by adding a cost to the unit price due to risk.

For example:

Company 1's split without the risk factor would be as follows;

$$\begin{aligned} x &= \frac{110 - 100(1.0)}{110 - 100} \\ &= .04762 \\ f_1(x) &= \left[\frac{1(.04762)}{|.04762|} \left(\frac{\arctan(75|.04762|^2)}{90} \right) + 1 \right] .5 \\ &= .6124 \end{aligned}$$

Company 1's split would be 61.24%.

However, company 1's split with a 20 percent risk factor applied to its unit price would be as follows;

$$\begin{aligned} x &= \frac{110 - 100(1.2)}{110 + 100} \\ &= -.04762 \\ f_1(x) &= \left[\frac{1(-.04762)}{|-.04762|} \left(\frac{\arctan(75|-.04762|^2)}{90} \right) + 1 \right] .5 \\ &= .4464. \end{aligned}$$

As a result of the risk factor, company 1 would now get 44.64% of the split.

It should be noted that if the company determined to be at risk submits a unit price larger than the other source, the risk factor would not be applied to the risky company's price. This is due to the assumption that the low bid unit price is only subject to the price factor variable in the x

equation. In this instance, the constants in the $f_1(x)$ formula could be adjusted according to how sensitive the SPO wanted to make the formula with regards to price deltas.

With a price factor included in the formulation of x , the SPO is not restricted by the formula to use only unit prices to determine the split. The SPO can take into account any factor, such as a price support factor or a risk factor, that can affect management's evaluation of the contractor's unit price. It should be noted that there are many instances when the price factor, in the formulation of x , would be zero. Some examples of this would be when both contractors are equally capable in producing the product, the second source submits a bid lower than the original source and the second source's risk factor is null, or the SPO determines the competition will be head-to-head with no price factor consideration. Once a value is determined for the price factor, the SPO can turn its attention to the $f_1(x)$ formula to determine the actual split.

Modified Formulation of $f_1(x)$

In Solinsky's general formula,

$$f_1(x) = \left[\frac{Ax}{|x|} \left(\frac{\arctan(B|x|^C)}{90} \right) + 1 \right] \cdot .5 \quad (40:B-1)^{(1)}$$

where the constants A, B, and C, values greater than zero, can be varied independently or in conjunction with each other to determine a split value. According to Solinsky, the constants can be changed in conjunction with each other to

implement a price support factor (41), but the problems associated with this technique have previously been explained under the subheading Drawbacks of Varying the Constants A, B, and C. This drawback has been eliminated due to the price factor variable in the formulation of x . The following section will discuss the elimination of the constant A. By doing so program management has one less constant to deal with in making the $f_1(x)$ formula fit their objectives.

The Constant A. It is felt that the constant A can be eliminated from the $f_1(x)$ equation without losing any effectiveness of the equation to determine a split value. As discussed in the section, Drawbacks of Varying the Constants A, B, and C, the constant A has an impact on the split value other than limiting the maximum split for which its use was intended (41). As the constant A becomes smaller, it not only limits the maximum split, it also makes the formula less sensitive to price deltas. This causes another factor to be taken into consideration which only complicates management's decisions on what values to assign to the constants.

If A were eliminated from the equation, the SPO would have one less constant to deal with. However, the SPO could still implement a minimum quantity requirement if needed. Moreover, this MQR could be used without making the formula less sensitive to unit price deltas if the split covered the required minimum quantity. For example, if the SPO determined the MQR to be 30 percent for each contractor and the

split value from the formula indicated the split should be 80/20 then the MQR would be implemented with a resulting 70/30 split. If, however, the formula split was 60/40 then the MQR would be covered and not be a factor. A technique on how to determine a company's MQR is discussed in the Definition section of this chapter.

The problem with using A, is the ambiguity of its impact on the formula when given a value other than one. Using A in conjunction with B and C further complicates and clouds the simplicity and usefulness of the formula to reflect management's objectives. Therefore, it is recommended that the constant A be eliminated from the $f_1(x)$ formula in favor of a predetermined MQR. The modified general formula would thus become

$$f_1(x) = \left[\frac{x}{|x|} \left(\frac{\arctan(B|x|^C)}{90} \right) + 1 \right] .5 \quad (4)$$

with the MQR as a limiter if required.

Decision Rule Heuristic

Introduction. Given that the constant A has been eliminated from the $f_1(x)$ formula, the development of a heuristic to give the SPO some basic guidelines on what range of values to apply to B and C has been simplified. However, it should be understood that each acquisition is unique in and of itself, and the guidelines presented hereafter must necessarily be of a general nature.

The Constant B. The constant B provides the greatest flexibility to the user because it can be adjusted to any positive number. However, due to the formula's asymptotic properties, the larger B gets above 300 the incrementally less influence it has in determining the split. For example, with large unit price differences (i.e., 25% to 50%), 80 to 95% of the split between 50 and 100% is taken into account when the range for B is from 1 to 300. In most instances the benefit of changing the value for B comes when B is given a value less than or equal to 300. Table III shows an example given a 25 percent price difference. Therefore, it is recommended that the highest value B should be given is 300.

When the unit price differences are small (i.e., 1 to 5%), changing B has only a small effect when C is equal to 2 as shown in Table IV. Therefore, when the SPO wants the formula to be sensitive to a small price difference, C should be changed to 1. The constant B can then be adjusted to any value up to 300 to determine the split.

The Constant C. The constant C causes the formula to be very sensitive or insensitive to a difference in unit bid prices, because C is an exponential value. For example, when there is a 10 percent unit price differential and $B=75$, if $C=1$ the split value is $91.3/8.7$. However, if $C=4$ the split value is 50/50. Tables III and IV gives examples of how sensitive the formula is when C is equal to 1.

Table III

Sensitivity Table: 25 Percent Price Difference
Between Co. 1 and Co. 2

C = 2 & B = the following:	Split for Co. 1 follows:	C = 1 & B = the following:	Split for Co. 1 follows:
1	50.4	1	53.5
25	59.5	25	89.0
50	67.6	50	94.3
75	73.8	75	96.2
100	78.3	100	97.1
150	84.2	150	98.1
200	87.8	200	98.6
250	90.0	250	98.9
300	91.6	300	99.0
500	94.9	500	99.4
1000	97.4	1000	99.7

Any whole number larger than 2 for C causes the formula, in most cases, to generate a split that approximates 50/50. As result, there are very few cases where C should be greater than 2. This is because the formula would not be needed if the sensitivity of the formula was such that the result was always a 50/50 split. The SPO would simply award a 50/50 split. Another reason not to use a value greater than 2 for C is because, no matter how close together or far apart the contractor's prices are they can be made equal or nearly equal by increasing the price factor in the formulation of x.

It is recommended, for the purpose of simplifying a decision rule heuristic, the values for C be limited from 1 to 2. It should be noted that program management may not want to limit C to 1 or 2 if the unit price differential is

greater than 50 percent. This is the approximate point where it could be useful to make C equal to 3 or 4 if a price factor was not going to be used. However, it is anticipated that the competitive nature of a dual source acquisition between capable and qualified contractors would produce price quotes well within a 50 percent price differential.

Table IV
Sensitivity Table: 2 Percent Price Difference
Between Co. 1 and Co. 2

C = 2 & B = the following:	Split for Co. 1 follows:	C = 1 & B = the following:	Split for Co. 1 follows:
1	50.0	1	50.3
25	50.1	25	57.7
50	50.2	50	64.6
75	50.2	75	70.3
100	50.3	100	74.8
150	50.5	150	81.1
200	50.6	200	85.1
250	50.8	250	87.8
300	50.9	300	89.7
500	51.6	500	93.6
1000	53.1	1000	96.8

Guidelines for Decision Heuristic

For the purpose of this heuristic the values for B will be limited to selected values between 1 and 300. The constant C will be limited to the values 1 and 2. However, values greater than 1 and less than 2 could be used if desired.

The first thing that must be determined is what are the

program office's objectives for a particular dual source acquisition. If the objective is to realize a price savings as quickly as possible and both sources can go head-to-head in competition with each other then the values for B and C should be 300 and 1 respectively. Using these values will result in the lowest average unit price to the government.

At the other extreme, where the objective is to give each contractor the largest possible share to keep the industrial base strong, but still provide competition based on unit prices, the values for B and C should be 1 and 2 respectively. These values will produce close to a 50/50 split for any unit price differences less than or equal to 100 percent. This would usually provide the government with the highest average unit price.

In most cases, the program office would not want to use the extreme values mentioned above. Rather, the SPO would use values that would represent a balance between cost savings and a strong industrial base. In this instance, the objective may be to provide competition between the two sources when one source is not capable, at the present time, to produce the majority of the units required. The program office could provide this contractor with a price support and then select values for B and C that would not be too sensitive to a price difference. Also, if the objective was to have a competition where management wanted a significant split for a large price difference and a insignificant split

for a small price difference, then the values for B and C could be 75 and 2 respectively.

The values of 75 and 2 for B and C could be the values used in the majority of the cases. According to Solinsky, the values used for the constants in the acquisition of the Night Vision Goggles were 1, 75, and 2 respectively for A, B, and C. The justification for using these values were "they made the graph scale well, however, there was no theoretical basis for these values" (41). As shown in Figures 7 and 8, these values cause their respective curves to split the extreme values for B and C. The use of 75 and 2 could be classified as the "normal" values to be used when the program office wants the formula to be neither sensitive or insensitive to price deltas. The normal values could be used when the SPO's objectives are to get a second source qualified and capable of producing the product.

There may be instances when the program manager wants the formula to be more sensitive than the "normal" values would provide, but not as sensitive as in the extreme case. For example, when the competition can go head-to-head with the objective of getting a reasonably low overall average unit price and keeping the high bidder producing at or above its MQR. If this were the case, then the constants could be adjusted to meet this objective whether the unit price differences were large or small. If the unit price differences were large the values for B and C could be 150 and 2 respectively. However, if the unit price differences were small

then B and C could be 75 and 1 respectively.

Conversely, if management wanted the the formula to be less sensitive than "normal" but more sensitive than under the extreme case for insensitivity then B and C could be adjusted accordingly to meet these objectives. In this instance, the SPO's objectives may be to keep both contractors operating at moderately high levels of efficiency. This objective would enhance the contractor's capability to ramp-up to higher rates of production for the following years competition. If the price difference is large, B and C could be adjusted to 25 and 2 which would moderate the severity of the split. With a small price difference there is no need to pick values other than the "normal" ones because the split would already be close to 50/50.

Figure 9 shows a continuum that clarifies the above explanation of the heuristic. To reiterate, this heuristic is very general but should be useful as a basic tool for deciding what values could be used to meet management's objectives in a dual source acquisition.

In the next chapter the modified split formula will be used with data from a potential dual source acquisition to demonstrate several situations in which the formula can be used. In addition, it will be used to validate a previous acquisition to determine if a savings would have resulted if the formula had been used.

	<u>B</u>	<u>C</u>	<u>SENSITIVITY</u>
Lowest Avg unit price	300	1	Highest
Large unit price delta	150	2	High
Small unit price delta	75	1	High
"Normal" values	75	2	Average
Large unit price delta	25	2	Low
Highest Avg unit price	1	2	Lowest

Figure 9. Guidelines for Decision Rule Heuristic.

IV. Acquisition Strategy and Testing of Split Formula

Introduction

The first part of this chapter will discuss an acquisition strategy used in conjunction with the split formula. This strategy's main goal is to create a competitive environment while reducing the possibility of gaming on the part of the contractors. This strategy will then be demonstrated using government budget estimates of unit costs for each contractor.

The second part of this chapter will use actual contractor bid data, which have been adjusted for proprietary reasons, to test the split formula. It will be determined whether or not the split formula could have produced a more advantageous contract for the government in terms of a lower overall contract price.

Acquisition Strategy

Before determining a strategy of acquisition to be set forth in the Request for Proposal (RFP), several assumptions should be presented. These assumptions are basic and necessary to the acquisition, but some individual assumptions could change from year to year.

Assumptions. The following assumptions will be used in conjunction with the acquisition strategy presented in this chapter.

- 1.) The decision to dual source has been made.

- 2.) Only two sources are qualified.
- 3.) Both contractors are willing to participate in a dual source acquisition such that technical data transfer takes place between both contractors.
- 4.) Both contractors are qualified to produce the product even though the new source may not have the capability to produce 100 percent of the government's requirements.
- 5.) During first year of the dual source acquisition, the new source has limited production capability which restricts a true head-to-head competition. However, each successive year the new source increases production capacity such that a head-to-head competition can take place after the second or third year.
- 6.) The procurement is over a period of 3 to 10 years or more.
- 7.) The procurement quantity per year is substantial enough to warrant dual sourcing.
- 8.) The price of the units produced does not take into account unit life cycle costs.¹
- 9.) A fixed price type contract will be awarded.

The assumptions are restrictive in the sense that the the second source initially has limited production capability. However, the acquisition strategy presented hereafter will still enable the government to introduce competition in

1. See Appendix if unit life cycle cost (LCC) is required to determine the unit price to be used in the formulation of x.

the first year just as if both contractors were able to compete head-to-head.

Request for Proposal. The techniques presented in the RFP for this acquisition strategy are general in nature and are not intended to be all inclusive. The program office needs to tailor their specific acquisition to enhance competition thus enabling the government to procure units at the best possible price. The basic philosophy of this strategy is that effective competition can take place whether or not both sources can compete head-to-head.

The basic question to be asked when writing the RFP is, "How much information should be given to each contractor regarding how the split will be determined, without jeopardizing effective competition?" In previous works dealing with second sourcing there are differences of opinion about what information should be given to the contractors. In the procurement of the Night Vision Goggles, each contractor was told that the price proposed for the range encompassing one-half the total procurement quantity would be used to determine the split (40:3). In the RFP for the GAU-8 Ammunition procurement, the contractors were told what percent of the award each contractor would receive given unit price deltas of the bids. Meeker insisted that the bidders must be aware of the split function because, if they are not aware of it, they may suppose that it is of a form that engenders reverse competition (29:6). Pelzer reasoned that contractors should be aware of their guaranteed minimum award requirement. For

example, when the guaranteed minimum is 30 percent for each contractor, the competition is reduced to only 40 percent of the total contract requirement (33:64).

The procurement strategy presented here proposes that the contractors should not be made aware of the information presented above for the following reasons. First, if the contractors know what bid range will be used to determine the split then there is the possibility they will submit a low bid for that particular range in an attempt to win the majority of the award. In addition, they could also submit inflated bids for the other ranges requested in the RFP which they think will fall into the actual award. Second, if the contractors know what percent of the award they could receive, given specified price deltas, they could increase their profits by bidding to lose. The opportunity also exists for the contractors to inflate their bids but still be within a price delta that would designate a 50/50 split. This possibility could take place if there was collusion between the two sources. Third, if the split function is given to the contractors, "they may not submit their best price opting instead to jockey for position on a mathematical curve" (40:3). Finally, if the contractors are guaranteed a minimum quantity or can infer what the minimum quantity split would be from the RFP (i.e., bids required on 25, 35, 50, and 65% of the total quantity, indicates minimum split is 25%), a contractor could increase their bids in an attempt to bid to lose. With a guaranteed quantity, the contractor's risk of

not getting some portion of the contract is lowered which could result in higher bid prices being submitted by both contractors. This would especially be the case if both contractors were bidding to lose. Therefore, each contractor should be required to bid on ranges covering the entire quantity to be procured.

RFP Strategy to Enhance Competition. One of the primary purposes of a dual source acquisition is to reduce the cost of units procured through competition. The previous section discussed how information given in the RFP could have an adverse effect on competition as a result of gaming. This section will discuss a strategy that should enhance competition by eliminating most of the potential for gaming.

When the RFP is being developed, the items mentioned in the previous section, namely, the range that will be used to determine the split, price deltas for a given split, the split formula, and the minimum quantity requirement, should not be included. This should eliminate the potential for gaming for those particular items. This strategy increases the uncertainty for the contractors, because they would have a difficult time determining how the split would actually be determined. In addition, they would not be sure they would be awarded any portion of the contract if their bids were too high. The only thing they could do is try to estimate, as accurately as possible, the bids of their competitor. The bids should be lower due to the increased risk of not knowing

what the possible outcome of the contract award will be.

The RFP should only instruct the contractors to submit bids on ranges covering the total quantity of the procurement. For example, if the total contract quantity was for 5000 units, the RFP could request a constant unit price, good for each unit, for every 10 percent range from 1 to 5000 units. As a result, the government should receive 10 prices covering the entire contract quantity. These prices could be used to plot a line on a graph to help determine a MQR. In addition, one of the ranges would be selected to determine the split. The contractors should only be told that one of the range bids will be used to determine the split. The government should also reserve the right to award 100 percent of the contract to the low bidder if the high bidder's prices are out of line and dual sourcing is not mandated.

The foregoing strategy would have the effect of increasing the risk of the contractor losing the contract or possibly getting a very small award if prices are too high. As a result, the contractors would be more inclined to submit their best prices for all the bid ranges because any range could be used to determine the split. One possible area for gaming is if one of the contractors could accurately predict what the others' bid will be. If this happened, the contractor could bid just low enough to beat his competitor. The only problem with this is that, if his prediction is too high, he would lose the majority award. Therefore, to reduce the risk of an inaccurate prediction, the contractor would

have to further decrease his bid just in case the other source's proposal was unpredictably low. Another area for possible gaming is for the established source to predict what the limited capability of the new source is. If this can be accurately predicted then the established source will know at what point the government must turn to him to meet the contract requirements. The established source could then inflate his bids for those ranges thereby guaranteeing himself higher profits. The flaw with this point is the established source may not know how much the government is willing to subsidize the new source to increasing the company's production capability. Plus, if they under estimate the new source's ability to increase production through additional shifts and/or production efficiencies, the established source may find itself as the high bidder. The end result of this strategy would be better competition with less probability for gaming.

It should be noted that this strategy is not in conflict with the assumption that the contractors are not equal due to limited production capabilities. (see Assumptions, #4). If the contractor with limited capability, wants to be responsive to the RFP, it will provide a price quote for each range. This would be true even if a range is beyond the current capability of the company. For the ranges beyond the contractor's capability, the program office should expect to see the "non-recurring" costs, i.e., facility costs, go up due to the contractor's requirement to increase capability

through facilitization. Therefore, the unit cost could still be competitive for use in determining the split. However, increased total costs and delays in production should be expected if the award to this contractor is above their current capacity. As a side benefit with this type of bid requirement, the program office can determine at what point of production the contractor must start facilitizing.

In addition to the contractors, not knowing what range will be used to determine the split, they will also not know how sensitive the split formula will be to price deltas. Therefore, the SPO maintains the ability to keep the contractors uncertain as to how the split will come out. This is true even if the split formula is discovered by the companies or they try to game the acquisition.

The RFP should be clear in explaining, in detail, how the split will be determined without releasing the above mentioned items. It should include adjustment factors, such as, use of government facilities, special tooling/test equipment, value engineering changes, and government furnished material, etc., if any, that will be used in the adjustment of range bids for parity purposes. In addition, the RFP should ask for cost and pricing data for several of the ranges as a check to evaluate the validity of the range bids.

It would also be wise to perform a should cost on each contractor. The should cost gives the SPO an idea as to what prices to expect. This helps the SPO establish, if desired, a competitive range with regards to the source's bids. If a

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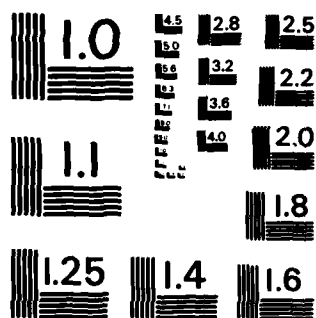
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source's bid is out of the competitive range, the SPO could choose to sole source the procurement or negotiate with the high bidder for a lower cost.

When the bids are received, another evaluation as to reasonableness should be conducted. If it is determined that all the bids are within the competitive range, it should then be determined if one of the sources has limited capability. The SPO should already know if one of the sources has limited capability, but they may not know exactly at what point the contractor's capability is exceeded. If there is a limited production capability constraint, the SPO could decide whether or not to incur additional contract costs to increase production capability. If the decision is made not to increase capability, the maximum award could be set at the company's MaxPR. This would be the case even if the split formula indicates a quantity larger than the company's MaxPR. Furthermore, the SPO could decide if there are any other factors that would cause an adjustment to the bids, i.e., price support factors or risk factors.

Bid Range Selection for Split Determination. After the evaluation of the proposals is completed, a bid range can be selected to use in the split formula to determine the split. It should be noted that the SPO could randomly select any range to determine the split. However, care should be exercised if a range is randomly selected, because the low bidder for that randomly selected range could be the high bidder

for the majority of the ranges. The result would be the high bidder receiving the majority of the award unless a price factor was used to increase the low bid unit price. Therefore, it is not recommended that a bid range be randomly selected.

The following techniques could be used to determine what values to use in the split formula. This is by no means an exhaustive list, but food for thought. The program office's imagination is the only limiting factor in determining what values to use.

The first, and possibly the simplest, method is to select the 50 percent range. This method was used successfully in the Night Vision Goggle acquisition (40:4). However, if the 50 percent range is above the current capability of the new source, the bid may not be as accurate as a bid within the current capability of the new source. The second method could take into account a source's limited capability. This could be done by selecting the bid range that encompasses the source's maximum capability without incurring additional costs because of required facilitization. This would be at the MaxPR and should be at the lowest bid point when facility costs are taken into account. This would therefore, be the the range where the new source has a comparative advantage against the established source even though the new source's bid is higher. A third possible technique is to select bids within the companies' minimum quantity requirement and maximum production capability. For example,

if the MQR is 25% of the total procurement for each contractor, and the MaxPR for the new source was currently 50% of the total procurement, the selected bid range to use could come from bids that fall within the above constraints. Another technique would be to use an average of those ranges. This narrows the choices and limits the possibility of selecting a bid range where the normally high bidder is selected because of one or two low bids. The final technique, which is not only simple but will generally give the overall low bidder the majority of the award, is to take an average of all the bid ranges. This technique will usually result in an average unit price that is near the 50 percent range bid. In addition, it reduces the possibility of favoring one company over the other due to differing price deltas. This is especially the case when the companies can go head-to-head for the entire procurement quantity.

When a unit price is selected for each company for input into the split formulation, the resultant split should fall within one of the bid ranges for which a proposed unit price exists. The total quantity awarded to each contractor multiplied by their bid unit price provides a total contract price for the required number of units to be procured. From this point, any other cost not associated with unit cost can then be added to determine a total contract price for each contractor. This assumes that the proposed unit prices for the given ranges are the contractor's best and final offer (BAFO).

Example of Acquisition Strategy

This section will detail an example of the proposed acquisition strategy discussed in this chapter. The assumptions are the same as those in the Assumptions section. In addition, an assumption is made that each proposal is the contractor's BAFO for any quantity within a given range. The data used in this example are actual SPO projections of unit costs for a proposed dual source acquisition. All the data have been adjusted for proprietary purposes.

The SPO issues a request for proposal to two qualified sources for a fiscal year procurement of 10,000 "weapon systems". The contractors are to give a unit price for each 10 percent range for the entire procurement. In addition, if extra facility requirements are needed for rates beyond the current capability of the contractor, they are to include this additional cost in a non-recurring category. Each contractor is told that one of the bid ranges will be used to determine the split with an example provided without divulging the split formula. Also, the SPO reserves the right to award 100% of the contract to one company if the bids are above a competitive range as determined from a previous should cost of each contractor.

Table V lists the proposals of each company for the required ranges. Company 2 is the new source and Company 1 is the established source.

Table V
Company Proposals

Bid range in units	Co. 2/unit proposal	add'l non- recurring costs	Co. 1/unit proposal	add'l non- recurring costs
1-1000	68,700	0	53,702	0
1001-2000	67,350	0	53,336	0
2001-3000	66,216	0	52,992	0
3001-4000	65,222	0	52,668	0
4001-5000	64,370	0	52,360	0
5001-6000	63,604	13.5 mil	52,006	0
6001-7000	62,920	17.0 mil	51,786	0
7001-8000	62,302	21.0 mil	51,516	0
8001-9000	61,734	24.0 mil	51,260	0
9001-10,000	61,202	25.0 mil	51,012	0

The SPO's objective in this example is to build an industrial base. This is done by insuring the new source receives a large enough quantity to enhance ramp-up capabilities for follow-on procurements. Another requirement is to remain under the established budget constraint of \$580 million. After the evaluation of the proposals, the SPO determines that a price support factor of 10 is needed to keep company 2 competitive for this years procurement.

The 50 percent bid range is selected due to it being the last range where additional non-recurring costs are not a

factor. Also it is decided that the split formula should have average sensitivity, therefore, the constants B and C will be 75 and 2 respectively. The split is now ready to be determined using the modified split formula where;

$$x = \frac{\text{Co. 2 price} - \text{Co. 1 price} + \left(\frac{\text{Price Factor}}{100} \right)}{\text{Co. 2 price} + \text{Co. 1 price}} \quad (3)$$

$$f_1(x) = \left[\frac{x}{1+x} \left(\frac{\arctan(B|x|^C)}{90} \right) + 1 \right] .5 \quad (4)$$

Therefore,

$$x = \frac{64,370 - 52,360(1.1)}{64,370 + 52,360} \\ = .058$$

$$f_1(x) = \left[\frac{.058}{1+.058} \left(\frac{\arctan(75|.058|^2)}{90} \right) + 1 \right] .5 \\ = .5787.$$

The resultant split would be 57.87% for company 1 (5787 units) and 42.13% for company 2 (4213 units). Referring back to the price proposals in Table V the associated bid for company 1 for 5787 units is \$52,006 per unit, and for company 2's 4213 units is \$64,370 per unit. These per unit costs equate to a total contract cost of \$572,149,532. This amount falls below the budget constraint of \$580 million, therefore, the SPO could possibly try to increase the total unit buy for this acquisition. However, if the budget constraint was exceeded, the SPO could reduce the price support factor and/or increase the sensitivity of the formula by adjusting

the constants B and C such that the total contract cost is within budget.

In the next section the split formula will be tested on a previous dual source acquisition. The purpose of this test is to determine if a savings could have resulted if the formula had been used to determine the split.

Validation of Split Formula

This section uses data, that has been adjusted for proprietary reasons, from a dual source acquisition that has been on-going for the last 5 years. A single year acquisition was selected to validate the split formula to determine if a savings would have resulted if it had been used. In addition, the data was manipulated such that the percent differences in prices remained the same as the original data.

Throughout this test, the low priced bidder will be called company 1 while the high priced bidder is called company 2. This will lessen the confusion when the company's prices are used in the formulation of x.

In this single year acquisition, the companies had to respond to an RFP that requested bids on four different quantities that represented a specific percentage of the total requirement of 6,033,387 units. The split was determined to be 57/43 after the SPO's evaluation of the proposals. The SPO was able to use a formula to interpolate each contractor's proposals for any quantity and price within the requested minimum and maximum quantities. The 57/43 split

was based on the percent difference of bids to some pre-determined award percentage. The resultant contract award to company 1 was 3,439,031 units for \$23,076,317 and company 2 received 2,594,356 units for \$19,371,654 for a total contract unit price of \$42,447,971.

In evaluating the split formula for this acquisition, the authors will use the SPO's interpolation technique to obtain the company's price per unit for each 10 percent increment of the total quantity requirement. These prices will then be plotted on a graph to determine a MQR. A quantity range will be selected and the unit prices will be used to determine the split.

Tables VI and VII shows the data for each company's bids for the 10 quantity ranges.

Table VI
Company 1 Bids

% of Total Qty	Quantity	Total Cost	Avg Unit Cost
> 0 ≤ 10	603,339	\$16,367,884	\$15.0565
> 10 ≤ 20	1,206,678	20,594,388	9.4722
> 20 ≤ 30	1,810,016	26,272,279	8.0558
> 30 ≤ 40	2,413,355	32,472,123	7.4676
> 40 ≤ 50	3,016,694	38,264,476	7.0398
> 50 ≤ 60	3,620,032	42,719,894	6.5495
> 60 ≤ 70	4,223,371	44,908,936	5.9016
> 70 ≤ 80	4,826,710	43,902,163	5.0481
> 80 ≤ 90	5,430,048	38,770,132	3.9627
> 90 ≤ 100	6,033,387	28,583,400	2.6293

Table VII
Company 2 Bids

% of Total Qty	Quantity	Total Cost	Avg Unit Cost
> 0 ≤ 10	603,339	\$11,018,070	\$10.1353
> 10 ≤ 20	1,206,678	19,048,399	8.7611
> 20 ≤ 30	1,810,016	26,238,254	8.0454
> 30 ≤ 40	2,413,355	32,931,488	7.5733
> 40 ≤ 50	3,016,694	39,278,123	7.2262
> 50 ≤ 60	3,620,032	45,361,556	6.9545
> 60 ≤ 70	4,223,371	51,234,489	6.7328
> 70 ≤ 80	4,826,710	56,933,032	6.5465
> 80 ≤ 90	5,430,048	62,483,376	6.3864
> 90 ≤ 100	6,033,387	67,905,302	6.2465

It should be noted that company 2 has a lower unit price than company 1 up to and including the 30 percent ranges. After that point company 1 becomes the low priced bidder. Therefore, care should be exercised when selecting a range to determine the split so that it is representative of the relationship of unit prices between the companies.

Figure 10 shows the data from Tables VI and VII plotted on a graph to help in the determination of a MQR. An analysis of Figure 10 indicates that the curves not only intersect at the 30% range but also start to flatten out. This indicates that production rates are such that price stabilization is occurring. Therefore, in this test the MQR will be 30 percent for each contractor. The MQR will be a limiter only if the split results are greater than 70/30.

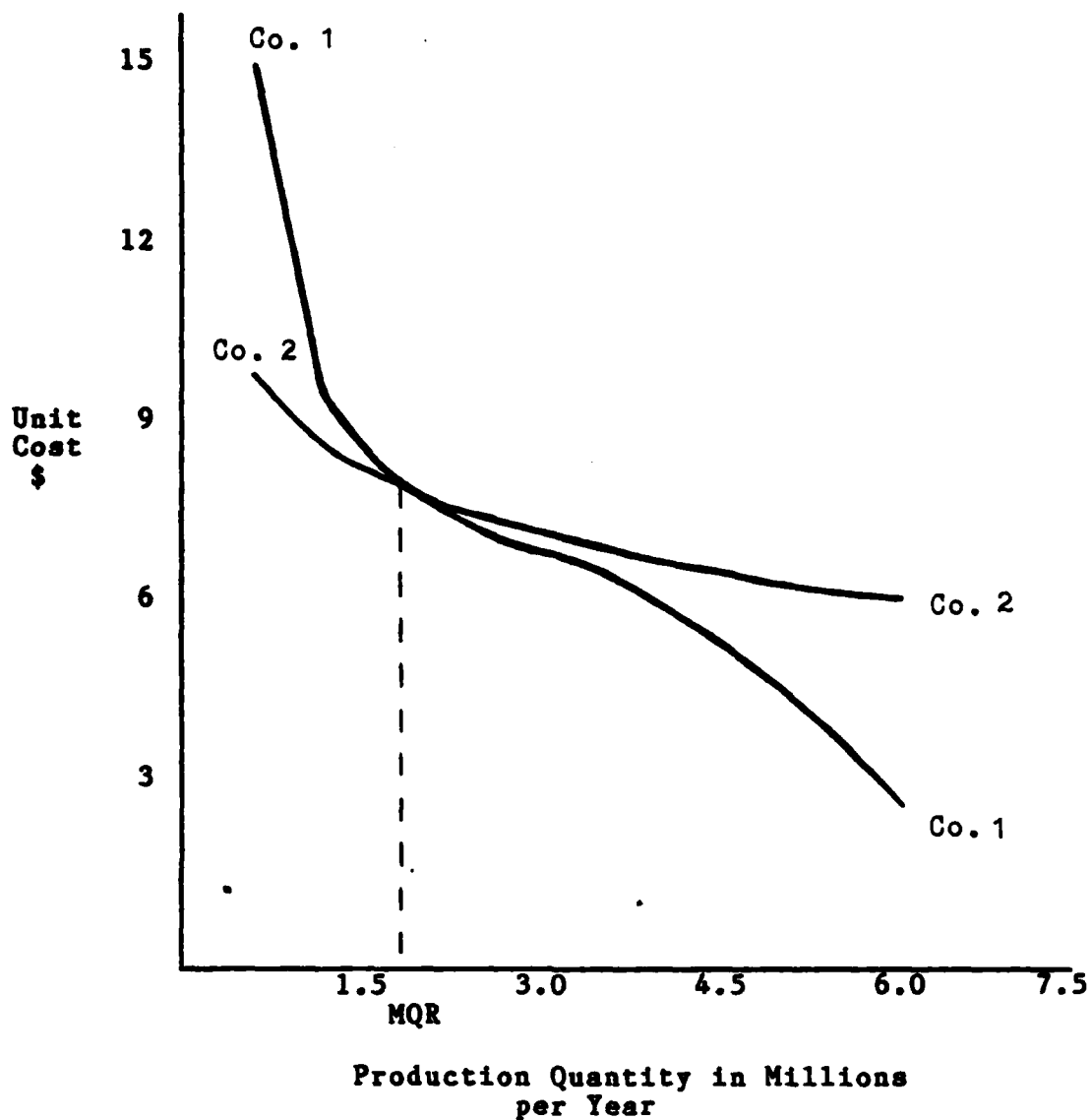


Figure 10. Plot of Companies' Bids.

In this case both contractors have the capability to produce the total government requirement without undue risk for non-performance. As a result, the competition can be head-to-head. Therefore, it will be assumed that the SPO's objective in this procurement is to obtain a low average unit price by increasing the split formulas sensitivity to price

deltas. In addition, no price support or risk factors are required.

In the first test of the split formula, the constants B and C will be 75 and 1 to reflect the SP0's objective for formula sensitivity associated with a small unit price delta (see Chapter III, Figure 9). Also the 50 percent bid range for both companies will be used to determine the split.

Test 1.

$$x = \frac{7.23-7.04 (1.0)}{7.23+7.04}$$

$$= .0133$$

Note: Unit Prices for each test where rounded to the nearest whole cent to determine x.

$$f_1(x) = \left[\frac{.0133}{|.0133|} \left(\frac{\arctan \left(\frac{75|.0133|1}{90} \right)}{90} + 1 \right) \right] .5$$

$$= .7496$$

The split from the formula indicates that company 1 would receive 74.96% of the total award. However, it was previously determined that the MQR was a limiting factor if the split was greater than 70/30. This is the case in this test, therefore, the split would be 70% for company 1 or 4,223,371 units, and 30% for company 2 or 1,810,016 units.

The resultant total unit contract cost would be as follows. Company 1's 70% bid was \$5.9016 per unit. Therefore their total unit contract award would be: \$5.9016 x 4,223,371 units = \$24,924,646. Company 2's 30% bid was \$8.0454 per unit. Therefore their total unit contract award would be \$14,562,302 (\$8.0454 x 1,810,016 units).

The total unit contract would thus be \$39,486,948 as compared to the actual single year award of \$42,447,971 for

this acquisition. The possible savings could have been \$2,961,023.

Test 2. The 50% range will again be used but the formula will be made less sensitive to the price delta by making B=300 and C=1.5. The results are as follows:

$$x = \frac{7.23 - 7.04(1.0)}{7.23 + 7.04}$$

$$= .0133$$

$$f_1(x) = \left[\frac{.0133}{|.0133|} \left(\frac{\arctan \left(\frac{300|.0133|^{1.5}}{90} \right)}{90} + 1 \right) \right] .5$$

$$= .6373$$

Company 1 would receive 63.73% or 3,845,078 units of the contract and, company 2 would receive 36.27% or 2,188,309 units of the contract. The resultant total unit contract award for company 1 and 2 is as follows:

$$\text{Co. 1} = \$5.9016 \times 3,845,078 \text{ units} = \$22,692,112$$

$$\text{Co. 2} = \$7.5733 \times 2,188,309 \text{ units} = \underline{\$16,572,721}$$

$$\text{Total contract cost} = \$39,264,833$$

$$\begin{array}{r} \text{The savings could have been: } \$42,447,971 \\ - \underline{\$39,264,833} \\ \$3,183,138 \end{array}$$

It should be noted that, even though the formula used values for the constants that made it less sensitive to price deltas, the split was such that it caused an increase in potential savings. This is due to one unit price being valid for a single 10% price range which covers over 600,000 units. In Test 2, company 1's total units dropped but was still within the 70% price range. Conversely, company 2's total

units increased and moved up to the 40% price range which had a lower unit cost. Therefore, the result was a lower total contract price.

If one price is good for any quantity within a range and the split award would be just below the next higher range, consideration could be made to adjust the split to get the lower unit price. In addition to the contractors providing bids for different quantity ranges, the SPO could request that each contractor provide a formula that would provide a price for any quantity within range. Then once the split is determined the contractor's interpolation formula could be used to get a contract price.

Test 3. The 50% range will again be used along with the "normal" values for B and C; 75 and 2. This test will determine if the split formula could still provide a contract savings using standard formula sensitivity. The results are:

$$x = \frac{7.23 - 7.04(1.0)}{7.23 + 7.04}$$

$$= .0133$$

$$f_1(x) = \left[\frac{.0133}{|.0133|} \left(\frac{\arctan \left(\frac{75|.0133|^2}{90} \right)}{.5} + 1 \right) \right] .5$$

$$= .5042.$$

In this test company 1 would be awarded 50.42% or 3,042,171 units of the contract. Company 2 would receive 49.58% or 2,991,353 units.

The resultant total unit contract price would be:

Co. 1 = 6.5495 x 3,042,171 units = \$19,924,699

Co. 2 = 7.2262 x 2,991,353 units = \$21,616,115
Total Contract Cost \$41,540,814

Even when the formula has "normal" sensitivity the savings could have been:

\$42,447,971
-\$41,540,814
\$907,157

In this validation a 50/50 split would be required before the actual contract produced a more advantageous contract. This is due to the large number of units within each range. Obviously, if a price was available for each unit, the actual contract award and the award using the split formula would have been equal at the actual split of 57/43. Therefore, the sensitivity of the formula needed to be such that the split was larger than 57/43 to show a savings.

The split formula has a high degree of flexibility in determining a split. It has been shown that use of the split formula has the potential for saving the government money as shown in the tests above. However, the most important aspect of the acquisition is how the RFP is structured to enhance competition. In addition, the bid ranges can have a significant effect on the savings potential, especially if a range covers a large number of units.

The split formula and acquisition strategy concepts presented in this chapter provides a plan whereby the SPO can structure a procurement to enhance competition. This strategy could also provide a lower overall contract price to the government.

V. Conclusions and Recommendations

Three techniques have been presented in this thesis. They have the potential to aid the program manager in successfully dual sourcing an acquisition. They are; 1) the determination of a Minimum Quantity Requirement, 2) the development of split formulas and, 3) an acquisition strategy to enhance competition for the entire government requirement, even if one contractor has limited capability.

The first technique, determination of a MQR, is important because contractors must receive a substantial enough quantity to keep them producing at a level of efficiency which enables them to be competitive. Being competitive not only means providing the government with a reasonable price as compared to the other source, but also means enabling the contractor to enhance ramp-up capability in the event of a larger award on a follow-on contract. The MQR is determined by plotting bids on ranges that cover the entire government requirement. A point is then selected on the resultant curve as the MQR for each contractor.

For some instances, when the bids are plotted, a straight line will result. In this instance, it may be difficult to determine a MQR. If this is the case, it is recommended that more data points be acquired and plotted and/or an evaluation of the contractors' facility be conducted to determine at what point their ability to produce becomes inefficient. The MQR technique can be used with any

other factor to determine the minimum award. Chapter III provides a more detailed development of the MQR.

The second technique developed was how to determine the split each contractor would be awarded. Chapter III developed a revised split formula from one that was used in a previous acquisition. The revised equation allows the unit price of the low bidder to be adjusted by a "price factor". This "price factor" can be any factor the SPO thinks has a bearing on the bid proposals (i.e., risk, subsidy, etc.). Also, one of the constants used to adjust the maximum split quantity was eliminated from the formula. This was done because the constant had an undesired affect on formula sensitivity. The elimination of this constant reduced the complexity of the formula. A decision rule heuristic was developed to give the SPO some ideas on what values to assign the remaining constants, given different objectives and circumstances.

It is recommended that the split formula be used in a dual source acquisition. Chapter IV illustrated the savings that could have resulted if the formula had been used on a previous acquisition. The split formula is very flexible and has unending potential in ways it can be manipulated to determine the split. However, the split can produce little benefit to the government if the acquisition itself allows for ineffective competition.

The third technique developed an acquisition strategy to enhance competition. The increased competition potential

should have the effect of providing a lower priced contract to the government. The goal of this strategy is to increase both contractor's uncertainty regarding what amount of the award each will receive. As the risk of not getting a portion of the contract increases the contractor's bid will decrease. The government can be assured of receiving higher priced bids if the contractors know what the MQR is or what the split will be in advance of the award. This is because the risk of not receiving a portion of the contract is much lower. Therefore, the contractors do not have to be as competitive as they otherwise would with high uncertainty of contract award which leads to higher prices. As a result, risk works to the benefit of the government at this stage of the acquisition.

When the RFP is written, care should be given to the number of ranges for which a bid is required. The ranges should cover the entire quantity requirement. However, a tradeoff between the number of competitive bid ranges required and the difficulty a contractor would have putting together a proposal should be considered. The more ranges required provides the government with more points to plot to determine the MQR. It also reduces the quantity of units within each range, thus enhancing the possibility of a more accurate proposal. However, when more ranges are required, the greater will be the difficulty and cost in developing and preparing the proposals. It is recommended that at least five ranges be required for bid as a minimum with 10 being

the norm. When the government requirement is large, more ranges may be needed to keep the total number of units within each range to a reasonable level. This is because one price should be proposed for any quantity within a given range. Another technique would be to require contractors to provide a formula for which a price could be determined for any quantity within a given range.

Overall, it is recommended that the techniques described in this thesis be used in a dual source acquisition. An evaluation could then be conducted to determine lessons learned and how much savings resulted, if any. It is the feeling of the authors that contractors will not like the acquisition strategy presented here. This is because the strategy increases their risk of not getting a substantial portion of the contract. Thus the contractors may feel they have to lower their bids to reduce the risk of not getting a substantial award. In addition, the authors feel that the techniques presented in this work will increase competition between sources resulting in a potential savings to the government.

Recommendations for Further Research

Two areas are recommended by the authors for further study. The first area encompasses the determination of the Minimum Quantity Requirement as discussed in Chapter III. Additional research should be conducted to determine at what quantity level a contractor's bid is uncompetitive and what

factors cause the increase in price. Along with this, additional research could be conducted to determine at what production level a contractor's capability to ramp-up for follow-on competitions is enhanced. Research in these areas should include the factors that cause increased prices and bottlenecks in production ramp-up capability.

The second area where additional research would be beneficial is selecting and assigning a value to the "price factor" in the formulation of x . This research should deal with ways of determining factors, such as risk, and how much weight should be assigned to these factors. The methods used in the determination of a weight have more significance than the factor itself. The factors are merely a reflection of the SPO's judgement. The factor value must reflect the actual value of these judgements when compared to the range bid.

Appendix: Life Cycle Cost Model Equations

The following Life Cycle Cost (LCC) equations could be used to determine what the projected unit LCC is anticipated to be. The unit LCC cost for each company could then be used in the formulation of x to determine the split. These equations were used to determine the unit LCC in the F-16 canopy acquisition. Data element definitions follow the equations.

1. ACQUISITION COST

Costs for production and option CLINs shall be multiplied by the highest quantity in the "Y" range. These costs will then be added to calculate the acquisition costs.

Production costs (PRODC) will be determined by multiplying the number of shipsets procured (NAC), the average price per shipset (PRICE), and a nominal percentage factor to represent the contractor's handling charge for Government-Furnished Equipment (CLOAD), as indicated below.

$$\text{PRODC} = (\text{NAC})(\text{PRICE})(\text{CLOAD})$$

2. BASE SPARES QUANTITY (BSTK)

$$\text{BSTK} = \left[\frac{(\text{POH})(1-\text{RIP})}{(\text{M})(\text{MTBMA})} \right] t + 1.5 \sqrt{\left[\frac{(\text{POH})(1-\text{RIP})}{(\text{M})(\text{MTBMA})} \right] t}$$

where t = average pipeline time in month

$$t = (\text{RTS})(\text{BRCT}) + (\text{NRTS} + \text{CONDB})(\text{OST})$$

This equation computes the number of spares required for each base to fill the base repair pipeline

including a safety stock to protect against random fluctuation in demand.

3. BASE SPARES COST (BSC)

$$BSC = (M) (BSTK) (UCB)$$

This equation computes the cost to provide base repair pipeline spares for all bases.

4. DEPOT SPARES QUANTITY (DSTK)

$$DSTK = \frac{(POH) (NRTS) (DRCT) (1-RIP)}{(MTBMA)}$$

This equation calculates the number of spares required to fill the depot repair pipeline.

5. DEPOT SPARES COST (DSC)

$$DSC = (DSTK) (UCD)$$

This equation computes the cost to provide depot repair pipeline spares.

6. BASE MAINTENANCE MANHOURS (BMMH)

$$BMMH = \frac{AOH}{(M) (MTBMA)} \left[PAMH + (RIP)(IMH) + (1-RIP)(RMH + BCMH) + (1-RIP) (RTS) (BMH) \right] + \frac{(AOH) (SMH)}{(M) (SMI)}$$

The first term computes the direct base maintenance manhours per base per year including preparation and access time, repair-in-place time, removal and replacement time, bench check time, and the repair time for those items repaired in the base intermediate shop.

The second term computes the labor manhours to

perform scheduled maintenance per base per year.

7. BASE MAINTENANCE MANHOUR COSTS (BMHC)

$$BMHC = (BMMH) (M) (PIUP) (BLR)$$

This equation computes the cost of base maintenance manhours over the life cycle.

8. DEPOT MAINTENANCE MANHOURS (DMMH)

$$DMMH = \frac{(AOH) (NRTS) (DMH) (1-RIP)}{MTBMA}$$

This equation computes the direct labor manhours per year to accomplish depot-level repairs.

9. DEPOT MAINTENANCE MANHOUR COST (DMHC)

$$DMHC = (DMMH) (PIUP) (DLR)$$

This equation computes the cost to accomplish depot-level maintenance over the life cycle.

10. CONDEMNATION SPARES QUANTITY (QCS)

$$QCS = QCSB + QCSD = \frac{(AOH) (PIUP) (CONDB) (1-RIP)}{MTBMA} +$$

$$\frac{(AOH) (PIUP) (NRTS) (CONDO) (1-RIP)}{MTBMA}$$

11. CONDEMNATION SPARES COST (CSC)

$$CSC = (QCSB) (UCB) + (QCSD) (UCD)$$

This equation computes the cost of spares required over the life cycle to replace condemned items.

DATA ELEMENT DEFINITIONS

Note: (I) = PROGRAM OR ITEM INPUT VARIABLE
(S) = STANDARD VALUE
(C) = COMPUTED VALUE

- AOH - Average annual operating hours expected over the program inventory usage period for all items. (I)
- BCMH - Average manhours to perform a shop bench check, screening, and fault verification of an item prior to initiating repair action or condemning the item. (I)
- BLR - Base Labor Rate including direct labor and indirect labor and material costs. (S) (Ref AFLCR 173-10)
- BMH - Average manhours to perform intermediate level (base shop) maintenance on a removed item including fault isolation, repair, and verification. (I)
- BMHC - The cost of base maintenance manhours (direct and indirect) over the life cycle. (I)
- BMMH - Direct labor manhours per year to accomplish base-level repairs. (C)
- BRCT - Average Base Repair Cycle Time in months. The elapsed time for an item repaired at the base from removal of the failed item until it is returned to base serviceable stock (less time awaiting parts). For items of a "black box" variety (e.g. avionics LRUs), the repair of which normally consists of removal and replacement of "plug-in" components (SRUs), BRCT = 0.13 months (4 days). For other, nonmodular components, BRCT = 0.20 months (6 days). (I)
- BSC - The cost to provide base repair pipeline spares for all bases. (C)
- BSTK - The number of spares required for each base to fill the base repair pipeline including a safety stock to protect against random fluctuations in demand. (C)
- CONDB - Fraction of removed LRU's expected to result in condemnation at base level. Note: $RTS + NRTS + CONDB = 1$. (I)
- CONDD - Fraction of LRU's returned to the depot for repair (NRTS) expected to result in a condemnation at depot level. (I)

- CSC - The cost of spares required over the life cycle to replace condemned items. (C)
- DLR - Depot Labor Rate including direct labor and indirect labor and material costs. (S) (Ref AFLCR 173-10)
- DMH - Average manhours to perform depot-level maintenance on a removed item including fault isolation, repair, and verification. (I)
- DMHC - The cost to accomplish depot-level maintenance of failed items over the program inventory usage period. (C)
- DMMH - The direct labor manhours per year to accomplish depot-level repairs. (C)
- DRCT - Average depot repair cycle time in months. The elapsed time for a NRTS item from removal of the failed item until it is made available to depot serviceable stock. This includes the time required for base-to-depot transportation and handling and the shop flow time within the specialized repair activity required to repair the item. (S) (Ref AFLCR 173-10)
- DSC - The cost to provide depot repair pipeline spares. (C)
- DSTK - The number of spares required to fill the depot repair pipeline. (C)
- CLOAD - The nominal percentage factor (e.g. 1.10) to represent the contractor's handling charge for GFE. (I)
- IMH - Average manhours to perform corrective maintenance on a LRU in place without removal. (I)
- M - Number of intermediate repair locations (operating bases). (I)
- MTBMA - Mean time between maintenance action in flight hours. (I)
- NAC - Number of shipsets procured for an item. (I)
- NRTS - Fraction of removed items expected to be returned to the depot for repair or condemnation. (I)
- OST - Average order and shipping time in months. The elapsed time between the initiation of a request for a serviceable item and its receipt by the requesting activity. The value of OST is therefore a weighted average value must be calculated as shown below:

$$OST_{WT} = (\% \text{ CONUS BASES}) (.4 \text{ MONTHS}) +$$

$$(\% \text{ OVERSEAS BASES}) (.53 \text{ MONTHS})$$

The .4 months for CONUS and .53 months for overseas bases are standard factors. (S) (Ref AFLCR 173-10)

- PAMH - Average manhours expended on the installed equipment for preparation and assessment to the item; for example, jacking, unbuttoning, removal of other units and hook-up of support equipment. (I)
- PIUP - Program Inventory Usage Period. Operational service life in years. (I)
- POH - Expected operating hours for one month during the peak usage period for all items. (I)
- PRICE - The average price per shipset for an item. (C)
- QCS - Quantity of spares required over the life cycle to replace condemned items. (C)
- RIP - Fraction of LRU Maintenance action which can be repaired in place without removal. (I)
- RMH - Average manhours to fault isolate, remove, and replace the item on the installed equipment and verify restoration of the equipment to operational status. (I)
- RTS - Fraction of removed items expected to be repaired at base level. (I)
- SMH - Average manhours to perform a scheduled, periodic, or phased inspection of the installed item. (I)
- SMI - Operating hour intervals between scheduled, periodic, or phased inspections on the installed item. (I)
- t - Pipeline time in months computed by the following equation:

$$t = (RTS)(BRCT) + (NRTS)(OST)$$
- UCB - Average unit cost for a spare of the item at base level. (I)
- UCD - Average unit cost for a spare of the item of depot level. (I)

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The injection of competition into the production phase of an acquisition is an important issue in today's defense acquisition environment. Developing a second production source is the primary means of achieving this type of competition. Various techniques to accomplish production competition have been used with mixed results.

This thesis reviews the theoretical basis for and the Government's policy regarding production competition along with the determination of second source applicability to a given program. In addition, this work reviews five methods of developing a second source, along with five methodologies for determining the award between two sources. After the award methodologies are discussed, one method (the Solinsky Technique) was chosen for a more indepth analysis.

The Solinsky award technique utilizes a continuous function which determines the quantity split as a function of the price differences proposed by the two sources. The equations used are flexible, in that they can be adjusted to reflect program management's assessment of how a given price difference translates into a split of the total quantity. However, the means of adjusting the formulas are vague and should more explicitly take into account factors, other than price, in determining the split.

This work proposed a modification to the Solinsky formulas to account for other factors, such as technical risk, in making the award determination. A decision rule heuristic was developed to serve as a guide in adjusting the modified formulas given certain objectives. An acquisition strategy was also developed around the split technique to enhance dual source competition while reducing the possibility of contractor gaming even though one contractor has limited production capability.

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